PETITION TO THE BOARD OF FORESTRY

TO LIST COHO SALMON

(Oncorhynchyus kisutch)

AS A SENSITIVE SPECIES

Prepared by the California Department of
Fish and Game

Presented to the California Board of Forestry on January 4, 1994

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Purpose of Petition

The Department of Fish and Game (DFG) is submitting this petition to the State Board of Forestry (BOF) for listing coho salmon (*Oncorhynchus kisutch*) as a sensitive species pursuant to Title 14, California Code of Regulations (CCR) Sections 919.12, 939.12 and 959.12. This petition follows the format outlined in the Forest Practice Rules (FPRs) for listing sensitive species. The intent of this petition and proposed rule is to recognize those streams which are adequately protected and make appropriate recommendations for other streams where it can be demonstrated that the present rules need bolstering. Some of the information in this document is repetitive because the rule categories overlap.

(1) Range and Distributional Status of the Species Including an Assessment of Occurrence in Timberland as Defined by the Forest Practices Act (FPA) and the FPRs.

Coho salmon are widely distributed in the northern temperate latitudes. In North America, coho spawn in coastal rivers and streams from California to Alaska. Today, principal populations of coho in California occur in the Klamath, Trinity, Mad, Eel and Noyo rivers, with other populations widely distributed in smaller, accessible, coastal streams south to Santa Cruz County (Figure 1). The present southernmost occurrence of coho is the San Lorenzo River. The South Fork Eel River supports the largest concentration of naturally reproducing fish (with little or no hatchery influence) and Brown and Moyle (1991a) and Brown et al., (in press) believe this stock to be the only remaining wild, big-river coho run left in California. The other big-river populations presently are largely maintained by hatchery production. Small captive breeding and pond rearing projects have been undertaken on several coastal streams in an attempt to bolster declining wild stocks and repopulate restored habitats.

Brown and Moyle (1991a) found historical records of coho salmon occurrence in 582 accessible streams or rivers from the Oregon border south to the Big Sur River, Monterey County. This estimate was developed using a combination of searches of published literature, review of file reports of fisheries agencies and personal communications (mail or telephone interviews) with persons involved in coho research and management in California. More recent records of surveys

FIGURE 1. Distribution of coho salmon, *Oncorhynchus kisutch,* in California.

(1987 or later) were available to them for only 244 of the streams historically used by coho. Based on their analysis of these recent records, Brown and Moyle (1991a) and Brown et al. (in press) believe only 132 streams (54 percent) out of the 244 total still support coho while 112 streams (46 percent) do not. The DFG recognizes that additional surveys may change these estimates for streams where no recent data exist as well as in historical coho streams with good habitat but no fish have been observed within the last three years.

Because hatchery-raised coho salmon in California constitute a significant portion of the population in some streams, coho populations have been classified by Brown and Moyle (1991a) and Brown et al. (in press) into three stock types: hatchery stocks; naturalized stocks that included a large proportion of hatchery fish at some time, but are the progeny of naturally spawning fish; and wild stocks having few or no hatchery-raised fish in their ancestry. These authors believe many of the streams containing naturalized stocks may also contain substantial numbers of hatchery strays. They base this in part on their belief coho are more abundant in streams near hatcheries as in the case of the Noyo River.

Hatchery Stocks

Hatchery coho salmon stocks have been used to bolster or re-establish naturally spawning coho populations throughout their range in California. The hatchery stocks that have been used to maintain these coastal river coho populations are of diverse origins, but they all have included fish from outside the river system receiving the plantings, and often from outside of California. This importation practice, formerly widespread throughout the Pacific northwest, is no longer being pursued by the DFG. The DFG's Salmon and Steelhead Stock Management Policy seeks to "...protect the genetic integrity of California salmon and steelhead stocks." This internal policy restricts hatchery stocking or importation of new stocks in all coho streams, based on a classification system that takes former stocking practices into account.

The DFG currently propagates coho salmon in four coastal hatcheries: Iron Gate (upper Klamath River),. Trinity River, Mad River, and Warm Springs (Russian River). The DFG also operates a coho salmon egg-taking station on the South Fork Noyo River. Privately owned and operated facilities that currently produce or have produced coho salmon include Rowdy Creek, Prairie Creek, Freshwater Creek, Hollow Tree Creek, Ten Mile River, Nicasio Creek, San Geronimo Creek and Big Creek.

Fish produced at hatcheries and other production facilities are used to supplement depleted runs, repopulate restored habitats and in attempts to re-establish extirpated populations. Information regarding California hatcheries, rearing facilities and egg-taking stations involved in coho salmon production is provided in Appendix A.

Naturalized and Wild Populations.

Brown and Moyle (1991a) developed a list of 582 California rivers and streams known to support coho salmon. This list of streams is reproduced in Table 1 to give the BOF an understanding of how extensive coho salmon once were in California. In addition, information regarding the presence of coho salmon in certain individual rivers and streams is contained in Appendix B and Appendix B-1. This information is intended to provide a general indication of the coho salmon's present range, distribution and occurrence in timberland in California between the Oregon border and the San Lorenzo River. It should be noted that not all of the data available is comprehensive in nature, but rather in many areas represents partial surveys or surveys only in some years. In addition, some of the data regarding coho salmon is in unpublished form or comes directly from various experts based on phone conversations or correspondence. Affiliations of all persons cited in this document as personal communications or sources of unpublished data are given at the end of the reference section.

Summary of Coho Salmon Distribution and Presence/Absence Data

Based on their review of streams for which recent reliable records (1987 or later) exist, Brown and Moyle (1991a) and Brown et al. (in press) estimate that overall, 45 percent of the streams in Del Norte County have lost their coho populations, mainly in the Klamath River system. Similar losses have occurred in other counties: Humboldt County, 31 percent , all in the Eel River system; Mendocino County, 41 percent; Sonoma County, 86 percent; and Marin County south, 56 percent. Brown and Moyle (1991a) believe that generally, the farther south a stream was located, the more likely it was to have lost its coho population. Again, the DFG recognizes additional surveys may change these percentages of streams no longer believed by Brown and Moyle (1991a) and Brown et al. (in press) to support coho salmon.

Coho Salmon Occurrence in Timberland as Defined by the FPA and the FPRs

Coho salmon have probably evolved in the niche provided by small coastal streams and rivers directly tributary to the ocean. The watersheds of these streams and rivers occur in areas that include private commercial timberlands subject to the FPRs.

Coho salmon life cycle habitat requisites presently known include: deep pools formed by large woody debris and boulders, undercut banks, dense shade canopy, and good water quality with year-round cool temperatures (Shapovalov and Taft 1954, Baker and Reynolds 1986). These habitat requisites most often occur in historically heavily timbered watersheds where they now coincide with landscapes where recent timber harvesting has been both continuous and intensive.

(2) Indices of Population Trends Describing the Abundance of the Species.

Data are not sufficient to estimate historical abundance of coho salmon in California. The best estimate of historical coho abundance comes from the South Fork Eel River where Benbow Dam presented the opportunity to conduct counts of adult fish passing through the ladder in route to their spawning grounds upstream. Counts at Benbow Dam are perhaps the most representative of historical coho numbers and where a clear decline in coho populations has been documented. Coho numbers there averaged about 15,000 fish annually during the 1940s and declined to about 1,800 fish annually during the period 1966 - 1975, which was the last ten years that counts were taken. This represents a decline of 88 percent in the coho salmon population in the South Fork Eel River during this period of record.

In the case of most other coho salmon streams, there is virtually no definitive data regarding historical coho abundance. Consequently, historical estimates of statewide coho salmon abundance are essentially educated guesses and speculations made by fisheries managers based on limited data, much of which are only occurrence records, hatchery records and personal observations. Many of the personal field observations cited in this document are personal communications from DFG employees. Absent any definitive historical data, speculative estimates are all that are available and most of these are contained in Brown and Moyle (1991a) and Brown et al. (in press).

In making their estimates of coho salmon abundance, these authors relied on their "20 fish rule" which assumed each stream that historically contained coho salmon or for which there were no recent data (1987 or later) had a basal population of 20 spawners. For each stream where an estimate of adult populations was available from the literature or respondents to their questionnaires, they used either the estimate itself or 20 fish, whichever was larger. For hatchery populations, they assumed the average population size based on available data starting in 1981-1982. For streams where hatcheries were located, they included both the average hatchery population and the estimated wild or naturalized population.

Using the above criteria, Brown et al. (in press) speculate historical coho salmon abundance was about 200,000 - 500,000 fish in the 1940s and according to the DFG's California Advisory Committee on Salmon and Steelhead Trout (1988), decreased to around 100,000 fish by the 1960's. The U.S. Heritage Conservation and Recreation Service (1980), as part of their evaluation of California rivers for inclusion into the Federal Wild and Scenic Rivers system, estimated there were 40,000 fish in the Eel River alone during this period. In 1979, the U.S. Fish and Wildlife Service (USFWS) estimated historical annual spawning escapements for the Klamath River system to be 15,400 - 20,000 fish, with 8,000 for the Trinity River. By the 1980's, Sheehan (1991) estimated coho stocks statewide declined to about 33,500 fish, the majority being of hatchery origin. Brown and Moyle (1991a) estimated the statewide coho salmon population in 1991 to be 31,000 fish, but emphasized hatchery populations contribute about 57 percent of the fish with natural and wild stocks making up the remainder.

Unfortunately, there is no way to test the reliability of these historical estimates, and Brown et al. (in press) recognize, as does the DFG, they should be viewed only as "order-of-magnitude" approximations. The DFG believes these authors have made a reasonable attempt to develop estimates of coho abundance. For example, their methodology estimated the Hollow Tree Creek (a tributary to the South Fork Eel River) population to be approximately 180 fish which compares favorably to actual counts of 162 fish made at the Hollow Tree Creek egg-taking station in 1989 - 1990. In addition, Brown and Moyle (1991a) and Brown et al. (in press) note their methodology likely over-estimates actual coho abundance because of their underlying assumption that streams known to historically support coho salmon had at least 20 fish still present, even if no fish have been observed in them since 1980. Irrespective of the speculative nature of the estimates that have been made regarding historical coho salmon abundance in California, the DFG and most fishery experts believe coho populations have experienced a dramatic and significant decline in the past 40 - 50 years.

In this and other sections of this petition, estimates of coho salmon abundance must be considered in light of the most recent cited period of record: 1985 - 1992. During this time period, California has experienced an extensive and severe drought that has caused extensive and widespread impacts to coho salmon streams. Consequently, recent estimates should be taken as a worst case scenario for many streams whose habitat is in reasonably good shape. The DFG believes coho populations occurring in streams that have critical habitat elements in good condition and have adequate protection, should be able to recover once conditions in the ocean improve and precipitation rates return to normal.

Using the educated, speculative estimates developed by various authors as discussed above, coho salmon in California, including hatchery stocks, could be less than 6 percent of their abundance during the 1940's, and have experienced at least a 70 percent decline in numbers since the 1960's. Also, many coho populations contain at least some fish of recent hatchery origin. Brown and Moyle (1991a) state hatchery stocks have fish in their ancestry from other river systems and often from outside California. While the practice of introducing non-native coho stocks no longer occurs in California, Bartley et al. (1992) believe these historical introductions may explain the overall lack of genetic differentiation of coho salmon from different California streams. However, low genetic differentiation among coho stocks has been observed throughout its range (Bartley 1992).

Based on current studies and surveys, Brown et al. (in press) speculate that coho stocks from naturally spawned fish (includes parents of wild, hatchery, or mixed origin) returning to streams each year since 1987 number about 5,000 - 7,000 fish, or about 1 percent of their historical number. They believe many of these fish are in populations of less than 100 individuals. These authors further estimate annual wild coho populations in river basins retaining indigenous populations number from fewer than 100 to 1,320 fish, the latter in the South Fork Eel River. They also believe these numbers are probably a substantial overestimate, given the absence of fish from many of the tributaries surveyed by Nielsen et al. (1991), and a more realistic estimate may be 600 fish.

Long-run coho populations have virtually been eliminated from many drainages (W. Jones, DFG, pers. comm.). In some coastal streams, Hope (1993) and Brown et al. (in press) indicate adult coho are only observed every third year, which they believe indicates that two of three brood cycles may already be gone. At the southern edge of their range, Brown and Moyle (1991a) and Hope (1993) state that wild stocks are no longer present in 10 rivers and streams and the southernmost remaining wild populations are found in Waddell and Scott creeks, Santa Cruz County.

The condition of stocks described above lends credence to the possibility that California's coho populations have high potential to continue declining. When a stock declines to fewer than 100 individuals, Brown et al. (in press) and Nelson and Soule (1986) believe it may face a risk of loss of genetic diversity which could hinder its ability to cope with future environmental changes. In addition, Gilpin and Soule (1990) postulate a random event such as a drought, major flood or variation in sex ratios may lead to extirpation if a stock is at such an extremely low level.

Adult returns (including grilse) to three of the four DFG fish hatcheries (reported below) that produce coho salmon have shown a moderate to significant decline in the past three years as compared to the 1980 - 1990 average. The

DFG's Noyo River egg-taking station showed similar declines.

Hatchery	1980-1990 Average	1991-1993 Average	Percent Decline
Iron Gate	1,523	1,066	30%
Trinity River	8,325	2,638	68%
Mad River	422	52	88%
Noyo River Station	971	273	72%

The above declines in hatchery stocks indicate ocean environmental conditions may be contributing to the decline of naturally spawning populations in recent years.

An exception to the above declines, is Warm Springs Hatchery which averaged 280 fish per year during 1980-1990 and 339 fish during 1991 - 1993 which represents a 21 percent increase between the two periods of record.

Naturally spawning coho stocks along the Oregon coast also appear to be numerically depressed. For 1990, Cooney and Jacobs (1992) found the standard index of coho abundance used by the Oregon Department of Fish and Wildlife (ODFW) was the third lowest value observed in the 41-year observation period of record. These authors estimated spawning escapement for standard sampling stream segments in 1990 averaged 16 fish per mile, the lowest since 1983, and compared to the 10-year average since 1981 of 30 fish per mile. They also estimated the total spawning stock size of naturally spawning coho salmon in Oregon coastal river and lake basins was 104,000 fish in 1990, 65 percent of the 161,000 fish spawning escapement goal set by the Pacific Fishery Management Council (PFMC). The coho escapement for 1991 was estimated to be 135,500 fish, compared to the PFMC goal of 200,000 (PFMC 1993).

In 1990, the ODFW began a reassessment of natural coho spawning habitat using a stratified random sampling technique developed by Jacobs and Cooney (1991) rather than the standard sampling of stream segments discussed above. Using the random method, Englemeyer (1992) estimated the number of coho salmon spawners for the Oregon coast was closer to 20,000 fish in 1990 and 33,000 fish in 1991. At the conclusion of the random sampling survey study in 1993, the ODFW plans to restate the 200,000 fish goal used by the PFMC and this will likely result in fewer fish proposed for harvesting in the ocean commercial and recreational fisheries off the Oregon and California coast.

In addition to providing insight into what might be happening with California coho salmon stocks, the above information regarding coho declines in Oregon is important to the California commercial and recreational coho salmon fishery. Most of the coho salmon caught in the ocean commercial and recreational fisheries of California originate in Oregon. According to Baker and Reynolds (1986), northern California coho contribute only about 10 percent of the California catch. The PFMC has recently implemented Amendment 11 to their Salmon Framework Plan. This action will reduce California impacts on Oregon coho consistent with the historic catch sharing ratio between the two states. Thus any reduction in harvest sought to protect Oregon coho will apply proportionately to the California fishery.

The documented recent decline in coho stocks is not just a California/Oregon problem, there have been similar dramatic declines throughout the species' range. Based on estimates derived from recently updated status information, mapping and analysis using geographic information system technology, the Wilderness Society (1993) believes coho salmon populations in the lower 48 states are now absent from 56 percent of their historic range, equivalent to endangered status in 13 percent, equivalent to threatened status in 20 percent and of special concern in 5 percent. They believe this means coho salmon populations are doing reasonably well in only about 6 percent of their historic range, all located in northwest Washington.

Nehlsen et al. (1991) recently assessed native naturally spawning stocks of Pacific anadromous salmonids that are declining. In their assessment, they rated California coho salmon populations south of San Francisco Bay at high risk of extinction, and populations north of San Francisco Bay were rated at moderate risk of extinction, except for populations in the Klamath River, which were classified as of special concern (declining but in no immediate danger). Higgins et al. (1992) modified and expanded the rating done by Nehlsen et al. (1991) for coho salmon populations in northwestern California. They rated the Scott River, Mad River, Mattole River, Pudding Creek, Garcia River and Gualala River at a high risk of extinction. They also rated the Trinity River, Wilson Creek, Lower Klamath River tributaries below Weitchpec, Redwood Creek, Little River, Humboldt Bay tributaries, Eel River, Bear River, Noyo River, Big River, Ten Mile River, Albion River and Navarro River as stocks of concern. They concurred with the remainder of the ratings developed by Nehlsen et al. (1991).

In February, 1993, the California Fish and Game Commission was petitioned to list coho salmon stocks in Scott Creek and Waddell Creek, Santa Cruz County, as threatened under the California Endangered Species Act. After reviewing the petition, the DFG recommended to the Fish and Game Commission that these stocks not be designated as candidate species at this time on the basis that there was nothing special about them relative to other stocks south of San Francisco Bay. The petition was subsequently withdrawn.

On October 19, 1993, the National Marine Fisheries Service (NMFS) was petitioned by a consortium of 23 conservation organizations, watershed protection groups and others to list coho stocks throughout their range in California, Oregon, and Washington as threatened or endangered under the Federal Endangered Species Act, for designation of critical habitat and for a status review of coho salmon throughout its range. The NMFS is currently reviewing the petition and has initiated a status review of coho salmon populations in the Pacific northwest (J. Bybee, NMFS, pers. comm.). Beginning on October 20, 1993, the NMFS has 90 days to make a finding as to whether the petition presents substantial scientific or commercial information indicating the petitioned action is warranted. The NMFS then has 12 months to make a decision regarding listing the coho salmon in all or only a portion of its range.

In November, 1993, the California State Lands Commission (CSLC) released a report entitled "California Rivers, A Public Trust Report" describing the current condition of the rivers and their watersheds in California and documenting the causes of their alteration and the nature and extent of their degradation. The report rates coho salmon stocks in the following rivers and streams to be at high or moderate risk of extinction, or of special concern: Smith River, Klamath River, Lower Klamath River tributaries, Trinity River, Scott River, minor Humboldt County tributaries, Redwood Creek, Wilson Creek, Mad River, Eel River, Bear River, Mattole River, Ten Mile River, Pudding Creek, Noyo River, Big River, Little River, Albion River, Navarro River, Garcia River, Gualala River, Russian River and small coastal streams (presumably south of the Russian River).

According to the CSLC, the report clearly argues the health of California's rivers to be stressed and their viability as sustainable ecosystems in peril. They believe it should no longer be disputed that there exists an urgent need for State agencies to undertake a comprehensive program of river basin and watershed protection and restoration. Until such a program can be enacted or adopted, they urge individual agencies to undertake to phase out or alter those activities presently permitted or tolerated which are revealed to be degrading the State's rivers and their watersheds. They further suggest such agencies should concurrently sponsor and implement actions conducive to the restoration of such rivers and watersheds.

(3) Biotic and Abiotic Factors Affecting the Population Viability or Status of the Species. Specific Attention Should Be Given to Factors Related to Forest Management and Harvesting. This Should Include Threats to Population and Habitat Viability, Including Direct, Indirect and Cumulative Effects from These and Other Threats.

The DFG believes there are factors in six main categories affecting coho salmon stocks in California today:

A) Stream Habitat Condition.

Coho salmon require year-round cool, high quality water, an abundance of shade, heavy riparian canopy, deep pools, cover in the form of large, stable, woody debris and undercut banks, and an unembedded gravel/rubble substrate. These habitat requirements are particularly important to juveniles which typically rear in the vicinity where they were hatched for one year before emigrating to the ocean (Baker and Reynolds 1986). When any of the above critical habitat components are degraded, coho salmon populations dependent upon that habitat generally will decline.

Lawson (1993) believes the long term decline of coho salmon populations parallels the deterioration of freshwater habitat caused by human disturbances. Several researchers, including Reeves et al. (1989), Hicks et al. (1991), and Pearcy et al. (1992), state coho salmon are especially vulnerable to loss or degradation of spawning, summer rearing, and winter rearing habitats whose critical components are discussed above. Pearcy et al. (1992) pointed to degradation of freshwater habitat as perhaps the largest contributor to long-term declines in coho productivity and recent shortfalls in escapement.

Many tributaries throughout the coho salmon's range have low gradients and were formerly optimal coho spawning and rearing streams. Large woody debris lodged in the flatter stream reaches and deep holes were scoured around them to form what Seddell et al. (1988) believe is optimal rearing habitat for coho salmon. The channel in these reaches was often braided and side channels developed which had slow water velocities, which according to Nawa et al. (1990), are best suited for young-of-year fish. Spawning gravels also washed into these sections from steeper tributaries that were inaccessible to coho salmon and were often deposited behind large woody debris where the gravels became available for spawning. Lisle (1981) found that unfortunately, these flat areas are also where problems persist if large quantities of sediment enter the stream system.

Problems with coho salmon stream habitat conditions involve three main areas of concern: sedimentation, loss of dense overstory shade canopy and subsequent increase in water temperature, and loss of large, woody debris. Each of these three concerns will be addressed separately below.

Sedimentation. Judsen and Ritter (1964) and the California Department of Water Resources (CDWR)(1982b) reported northwestern and central coastal California have some of the most erodible terrain in the world. Carver and Burke (1987) state there are major earthquake faults on land that almost all major rivers in the region follow. Many of the soil parent materials are over-steepened, pelted by intense rainfall, subject to flooding and very prone to landslides (CDWR 1982a). Natural erosive processes involving high rainfall, floods, unstable soils, sheet and gully erosion, and mass wasting can generate vast amounts of sediment and debris that is ultimately deposited into streams. Land disturbing activities caused by logging, road construction, mining, urbanization, livestock grazing, cropland agriculture, and other uses may also contribute sediment directly to streams or exacerbate sedimentation from natural erosive processes. Several researchers, including Janda et al. (1975), Wahrhaftig (1976), Kelsey (1980) and Hagans et al. (1986), report mass wasting of steep, erodible slopes that have been clearcut harvested and failure of roads on unstable soils have caused catastrophic erosion and subsequent stream sedimentation during floods as have occurred in 1955 and 1964.

As streams and pools fill in with sediment, flood flow capacity is reduced, resulting in increased lateral pressure. This makes streams wider, meander more, and causes loss of their undercut banks and other structure. Such changes cause decreased stream stability and increased bank erosion and subsequently exacerbate existing sedimentation problems. All of these sources contribute to the sedimentation of spawning gravels and in-filling of pools and estuaries used by coho salmon. Lisle (1981) found many north coast streams show signs of having harbored past debris flows and remain shallow, wide, warm, and unstable for decades after floods. Furthermore, Seddell et al. (1988) report large logs are no longer available to replace old logs that are still buried in some stream reaches due to logging in stream side areas.

Logging conducted prior to the FPRs induced damage described above to many coastal streams used by coho salmon and many of them have not yet fully recovered. Fisk et al. (1966) provided testimony to the State Interim Committee on Stream and Beach Erosion in 1956 indicating 925 miles of streams in California had been damaged or destroyed by early 1955 and this total damage had exceeded 1,000 miles by the end of 1956. In 1962, Calhoun and Seeley (1963) found 33 streams totaling about 55 miles were reportedly damaged that year. Fisk et al. (1966) reported preliminary surveys on the Garcia River and Redwood Creek revealed the Garcia River to be severely to moderately damaged by ongoing logging and road building along 52 of 104 miles of available habitat, and 68.5 of 84 miles of habitat in Redwood Creek were similarly damaged. Holman and Evan (1964) estimated all of the 70 miles of the potential habitat in the Noyo River during the late 1950s had been damaged by past logging activities prior to the mid-1940s. The U.S. Bureau of Reclamation (1973) surveyed Redwood Creek and the Ten Mile, Noyo, Big, and Gualala rivers and found all had been negatively affected by logging activities, road building, livestock grazing, or urbanization. They also reported some of the lower reaches of these streams were beginning to show signs of recovery.

Graves and Burns (1970) compared yields in 1964 of downstream migrant salmonids for South Fork Caspar Creek with yields in 1968, following logging road construction and right-of-way logging there in 1967. During the logging operations, large quantities of rocks and trees fell into the stream. Upon completion of stream clearance, over 99 percent of the 3.18 km (1.97 miles) study reach had been disturbed. The number of coho smolts in the study reach was 41 percent less in 1968 than in 1964. These authors reported similar results on the Little North Fork Noyo River.

Valentine and Jameson (1993) repeated aspects of Burns' work on the Little North Fork Noyo River in 1992 near the same vicinity as Burns' study reaches. While the total salmonid biomass was similar across the two studies and during the 1966 - 1969 and the 1992 time period, the species composition since 1969 has inverted from primarily coho salmon to primarily steelhead trout. While other factors may also be involved, these authors suggest that the decline in the stream channel's average depth in response to past logging practices seems the most likely instream parameter causing the inversion in salmonid species composition in Little North Fork Noyo River.

In some watersheds, logging which adds sediment and adversely impacts water quality, and cumulatively causes adverse effects, is also prolonging recovery in terms of overall sediment production, storage, and movement through stream systems. Some streams lack the channel gradient and hydrological capability of routinely flushing out their large sediment loads so pools remain filled and spawning gravels are clogged with silt for long periods.

Evidence is emerging that stability of spawning gravels may be a critical limiting factor for salmon. Nawa et al. (1990) found scour and fill of aggraded stream beds caused by minor storms (two year events) in southwest Oregon was sufficient to cause mortality of eggs and alevin. They also found runs of chinook salmon in Euchre Creek, a highly aggraded stream system, decreased from 2,000 to less than 200 and coho populations are now extirpated. Work by Payne and

Associates (1989) indicates gravels are extremely unstable in lower Klamath River tributaries, so mortality of eggs similar to that noted by Nawa et al. (1990) is likely occurring there. Decreasing stability of spawning gravels due to aggradation was asserted by the CDWR (1982b) to be the major cause of declines of salmon runs in the South Fork Trinity River. During the 1991 - 1992 season in Waddell Creek, Smith (1992 a,b) reported there were at least 3 probable coho salmon redds destroyed by scouring following a post-spawning storm.

Some north coast streams are so aggraded that surface flows are lost during summer months. Where tributaries join main rivers, Payne and Associates (1989) found that plugs of sediment often block migration routes for adult and juvenile salmonids. Coats and Miller (1981) speculated that many tributary watersheds spared from harvest prior to past floods have now been harvested and may experience substantial habitat deterioration in the event of a future major flood event.

Several researchers such as Puckett (1977) and Hofstra (1983) report pulses of sediment have also filled estuaries of many north coast rivers, greatly diminishing carrying capacity of these areas that have become vitally important to juvenile chinook salmon and coastal cutthroat trout. According to Brown et al. (in press), estuaries are also important to coho salmon because fry that rear there have higher growth and survival rates than those of stream fry. Furthermore, Tschaplinski (1982) and Hassler (1987) found growth and survival rates for fry in estuaries are independent of those for fry in streams and are not affected by adverse conditions upstream. Puckett (1977) found juvenile coho salmon in all areas of the Eel River estuary and both Puckett (1977) and Smith (1987) noted fish habitat in California estuaries was reduced or eliminated when the estuaries filled with sediment, gravel and debris washed in from upstream.

Major damage to riparian zones, with subsequent adverse impacts to fishery resources, results when large amounts of sediment fill lower stream reaches, particularly in valley bottoms. Lisle (1981) noted recruitment of conifers into stream side areas altered by debris flows may take more than a century. He also found even willows and alders have a difficult time colonizing stream side zones in highly aggraded streams because of gravel instability.

<u>Loss of dense overstory shade canopy and subsequent increase in water temperature</u>. Many watersheds supporting coho salmon have been logged more than once resulting in cumulative removal of most of the original dense conifer overstory shade canopy covering streams. This reduction in tall tree shade canopy along with the initial and continued logging of stands adjacent to the WLPZs, can produce significant increases in water temperature in some streams. Hagans et. al

(1986) reported water temperatures can also be adversely impacted by increased sedimentation of gravels and pools. They found this impact is caused by: 1) the loss of a reflective bottom; 2) the darker sediment (as opposed to clean gravels) stores heat from direct solar radiation which is subsequently transferred to the water column; and 3) water flow through the gravel interstitial spaces is reduced thereby exposing more of the water column to direct solar radiation and thus more heat.

It is possible that continued harvesting within WLPZs allowed under the FPRs, including operations done under an exemption or emergency notice, may be exacerbating existing water temperature problems in some streams because a significant amount of protective overstory canopy can be directly and/or cumulatively removed without using an adequate review process. As dense overstory shade canopy is removed and the stream is exposed to more direct solar radiation, water temperatures can increase.

Kubicek (1977) and the USFWS (1991) reported main river channels have become increasingly unsuitable for all salmonids during summer months due to high stream temperatures. Kubicek (1977) found over 25 percent of the pools in the main forks of the Eel River reach temperatures of over 26.7 C° (80 F°) during summer. The USFWS (1960) reported races of salmon spawned along the entire length of most north coast rivers as recently as the 1950s, but success of main river spawners has greatly decreased since the 1955 and 1964 floods (S. Downie, DFG, pers. comm.).

Loss of large woody debris. Large woody debris that is stable because it is well keyed-into the bank is very important to providing pools, instream cover, spawning gravel trapped behind it and general watershed stability. There was so much debris resulting from past poor logging practices that many streams were completely clogged and were total barriers to fish migration. In past years, the DFG, with the help of others, removed much of the debris in order to allow any fish passage at all. In order to achieve the objective of providing adequate fish passage, the DFG removed too much large woody debris from some streams.

Past and present harvesting practices have eliminated large trees, large logs, and other woody debris from streamside areas which could have otherwise recruited to the channel. This is particularly true for redwood, which takes many decades to decay and could have provided long-lived benefits to fish habitat and watershed stability. Repeated entries into WLPZs for sanitation salvage and harvesting under exemptions and emergency notices continue to further limit recruitment of large woody debris. Consequently, there is now very little recruitment of large logs and other large woody debris in many streams to replace old logs that have been washed out of the system, buried by large debris flows during floods, or removed decades ago to provide fish passage.

Additional problems affecting stream habitat condition. Dams have been constructed on some coho salmon streams and they adversely impact coho salmon because they eliminate access to historical spawning habitat; transfer water to other basins, thereby depleting flows necessary for migration, spawning, rearing, flushing of sediment from spawning gravels and transport of large woody debris; severely reduce spawning gravel recruitment; increase downstream water temperature and otherwise result in un-natural channel conditions that can adversely affect coho habitat. Other land uses affecting coho salmon include: gravel mining that eliminates spawning and rearing habitat and downstream recruitment of spawning gravel; agricultural and domestic diversion of stream flows, particularly during the summer months; riparian vegetation removal, bank erosion and sedimentation due to over-grazing; agricultural and urban run-off; highway construction that either constricted or altered flows through lagoons and estuaries; and sewage spills and run-off of dairy wastes into streams that can result in decreased dissolved oxygen levels lethal to fish.

B) Loss and Fragmentation of Coho Salmon's Historic Range.

Coho salmon stocks consist of a highly organized network of dynamically connected populations adapted to local stream conditions. Occasional interchange of genes between these genetically linked populations is beneficial to the species overall by providing greater diversity and thus greater ability to better adapt to ecological changes. According to Frissell (1993), each coho salmon population is geographically, evolutionarily and ecologically important so either the individual or cumulative depletion or extirpation of populations, or the fragmentation and severing of natural linkages (sources of genetic interchange) between populations, can precipitate rapid extinction of the species across large portions of its range.

Brown and Moyle (1991a) found historical records (covering many years) of coho salmon occurrence in 582 accessible streams or rivers along the California coast. According to Brown and Moyle (1991a) and Brown et al. (in press), recent records since 1987 indicate about 132 streams (54 percent) out of the 244 total (for which recent data exists) still support coho salmon while 112 streams (46 percent) do not. The DFG recognizes additional or more extensive surveys may change these percentages. Given the number and location of streams that historically supported them, it appears California coho salmon populations have been individually and cumulatively depleted or extirpated and the natural linkages between them have been fragmented or severed. Unless both kinds of impacts discussed above are eliminated and ultimately reversed, the DFG believes the long-term health of California's remaining coho salmon populations may be at significant risk.

The loss of coho salmon over significant portions of its range curtails or eliminates its functional role as a species in the ecosystem. Houston (1983) and Cederholm et al. (1989) indicate in freshwater, coho and other salmon species are prey items for numerous aquatic and terrestrial predator and scavenger species, and may contribute significantly to the nutrient budget of aquatic and riparian ecosystems. Salmon function in the ocean as an important food resource for numerous predatory animals.

C) Interactions between Wild Stocks and Stocks Produced by Hatcheries.

Non-native salmon or steelhead stocks historically have been introduced as broodstock in hatcheries and widely transplanted in many Pacific coastal rivers and streams. Altukhov and Salmenkova (1986) have shown anadromous salmonids transferred to other watersheds rarely persist for more than two generations, without assistance from artificial culture, due to lack of appropriate adaptations to their new environment. Withler (1982), in an extensive review of the literature, found no successful case of establishing a new run of anadromous salmonids by transplanting stocks anywhere on the Pacific coast.

In the past, the DFG has transferred non-native anadromous salmonids, including coho salmon stocks from the Columbia River basin, Alsea River, Washougal River and other sources, to try to increase runs and re-establish populations in California coastal streams. The DFG no longer allows such transfers of fish to or within California. The ODFW embarked on a similar coho salmon enhancement program in the 1970s using one broodstock to supplement runs in streams along the entire Oregon coast. Nickelson (1986) evaluated the ODFW program and showed introduced coho juveniles exhibited lower survival than native coho juveniles and native smolt output was decreased by competition. Smith et al. (1985) found adult returns to the stream were about equal in stocked and unstocked streams but subsequent smolt output was decreased in stocked streams. Solazzi et al. (1983) concluded from the evaluation that widespread transplantation of fingerling coho salmon lacked a sustained biological benefit. Nickelson (1986) showed coho salmon stocks in Oregon shifted from a balance of 50 percent hatchery and 50 percent wild fish to 85 percent hatchery and 15 percent wild fish.

Planting juvenile coho salmon from non-native hatchery broodstock into streams often results in some adult returns as "strays" to other drainages. When non-native hatchery strays spawn in the wild, Altukov and Salmenkova (1986) found young fish with some non-native genes may result. Studies by Riesenbichler and McIntyre (1977), Smith et al. (1985) and Chilcote et al. (1986) in other areas have shown juvenile salmonids spawned by stray hatchery fish and hatchery-wild hybrids have lower survival rates. Kapucinski (1984) reported juvenile fish that are hybrids or of hatchery origin may lack resistance to disease, appropriate behavior, or other traits critical for survival. Riggs (1990), Steward and Bjornn (1990), Waples (1991) and Hindar et al. (1991) found the impact of stock transfers increases dramatically if non-native anadromous salmonids are planted on top of wild populations for several generations. When this occurs, Altukhov and Salmenkova (1986) state there is a loss of local adaptations that may lead to extirpation of that local population.

Genetic changes in hatchery stocks of Pacific salmon have been documented and models have been recently constructed by Waples (1990a,b) and Waples and Teel (1990) to aid in understanding the consequences of these changes for the preservation of wild genotypes. In their recent review, Steward and Bjornn (1990) noted large differences in the genetic structure of wild and hatchery stocks can potentially lead to lower survival. They also noted supplementation with hatchery stocks can have positive, neutral or negative effects depending on the size of the wild population. Positive effects are primarily restricted to instances where the wild stock has been reduced to such low levels that much of the genetic variability has been lost. Negative effects can result from the stocking of hatchery fish that are poorly adapted to the local natural environment. Nickelson et al. (1986) found such fish can contribute maladaptive genetic material that has been influenced by selection in the hatchery or other stream systems rather than in the relevant environment.

Aside from the problems associated with historical introductions of non-native stocks, introduction of hatchery raised fish into the natural environment can result in competition between hatchery and wild fish. For example, Miller et al. (1990) found release of hatchery presmolts into Oregon streams reduced the density of wild juvenile coho salmon by 40 - 50 percent, and there was a subsequent reduction in adult returns. There are several possible mechanisms that might explain the losses observed. Juvenile coho salmon are territorial (Shapovalov and Taft 1954), and the larger hatchery fish can displace smaller wild fish. Puckett and Dill (1985) report fish with territories have an energetic advantage over those lacking a territory. Nielsen (in press) found introduction of hatchery reared coho salmon into the Noyo River led to displacement of wild coho from their usual microhabitats and shifts in foraging behavior. According to Dill and Fraser (1984), hungry fish are less responsive to predators, so mortality at high densities would be higher, especially for displaced wild fish. At high densities, Fraser (1969) found growth of coho salmon is depressed through intraspecific competition for resources, and mortality is increased. Shapovalov and Taft (1954) noted an inverse correlation between the number of downstream migrants and adult returns, implying that in years when intraspecific competition is low, downstream migrants are better able to survive in the ocean.

Competition for spawning sites among adults can occur. When wild stocks are small and hatchery supplementation occurs, hatchery fish may outnumber wild fish and monopolize the available spawning habitat. Fleming and Gross (1992) believe the negative effect of such competition can be magnified by the fact that naturally spawning hatchery stocks have lower spawning success than wild fish. Steward and Bjornn (1990) found hatchery stocks also may produce fewer smolts and returning adults.

The capture of broodstock itself can adversely impact small or declining wild populations. Due to small broodstock populations, pre-spawning mortality during capture or transport, differential viability of gametes in artificial situations, disease, and artificial selection, Verspoor (1988) and Bartley et al. (1992) believe wild brood stock typically contribute little genetic diversity to subsequent generations of hatchery fish. These authors also believe taking of larger numbers of wild fish for broodstock in an attempt to overcome these problems in hatchery stocks can increase the risks to wild populations. The nature and extent of this potential problem in California is not well known.

Because of the above problems encountered with historical transfers of non-native stocks and strong Legislative direction to protect, maintain and manage California's native fish and wildlife populations, the DFG's "Salmon and Steelhead Stock Management Policy" was developed. This internal policy, which seeks to minimize the interactions between hatchery and natural populations, can be summarized as follows:

> "It is the policy of the DFG to maintain the genetic integrity of all identifiable stocks of salmon and steelhead in California. To protect the genetic integrity of California salmon and steelhead stocks, each salmon or steelhead stream shall be evaluated by the DFG and the stocks classified according to their probable genetic source and degree of integrity. Management and restoration efforts will be guided by this classification system, and policies relating to artificial production must also be compatible with this classification system."

This policy is a strong statement for the conservation of natural coho salmon population viability in California.

Because reliance on hatcheries has not yet proven successful in restoring coho numbers without a concurrently high level of wild stock production, the need for maintaining high quality spawning habitat is even greater.

D) Ocean Conditions.

Lawson (1993) indicates ocean conditions are cyclical and have been less than favorable for coho salmon over the past two decades. It is unknown when more favorable conditions will return. Pearcy and Fisher (1988) found most variation in ocean mortality of coho salmon apparently occurs during the first few weeks of ocean life. Scarnecchia (1981) states near-shore conditions during late spring and early summer along the California coast may dramatically affect year-class strength. Ware and Thompson (1991) postulate upwelling along the Pacific coast of North America is driven by 40- 60-year cycles in wind patterns. Following an interval of generally favorable conditions during 1945-1975, Bottom et al. (1986) and Pearcy et al. (1992) noted upwelling declined along the Oregon coast, and marine survival of coho salmon declined at a similar rate. Brodeur (1990) found the diet of juvenile coho salmon in the ocean off the coast of Oregon and Washington shifted in years with varying degrees of upwelling. He concluded lack of food resources and intensive planting of coho smolts were leading to density dependent mortality in the ocean in some years. Bottom et al. (1986) believe coho salmon along the Oregon and California coast may be especially sensitive to upwelling patterns because these regions lack the extensive bays, straits, and estuaries found along the Washington coast that can buffer adverse oceanographic effects.

Marine food webs involving coho salmon and their relationship to coho population declines are poorly understood. Ware and Thompson (1991) present evidence that certain species used as food by coho salmon, such as Pacific sardines and hake (Pacific whiting), have undergone reductions in population size in the past century. Botsford et al. (1982) indicate there is a pattern of cyclic covariation between the catch of Dungeness crab and both chinook and coho salmon (cycle period of 10 years). The coho salmon data only covered the period 1952-1976, before the recent decline in catch, but Brown et al. (in press) believe the linkage of the two salmonids and the crab suggests a significant ocean component to salmon survival.

Freeland (1990) reported the average seawater surface temperature off British Columbia has increased significantly during the past 50 years, and the pattern of increase closely mirrors changes in global average air temperature. Roemmich (1992) reported similar patterns for coastal California. According to

Johnson (1988), relatively short term events like the recent (1982-83) and present (1990-to date) El Nino episodes can affect coho by reducing growth, survival, fecundity and thus overall numbers of fish returning to spawn.

Nielsen et al. (1991) noted some of the streams surveyed during their study had good to excellent spawning and rearing habitat, and W. Jones and T. Wooster (DFG, pers. comm.) also acknowledge the good quality of some Mendocino County streams. In spite of these favorable habitat conditions and extensive restoration or enhancement efforts, coho salmon are under-utilizing or not using some of these streams. The reasons are unknown for this lower than expected use by coho salmon, including what role ocean conditions may be playing in the lowered use. Consequently, Brown et al. (in press) recommend the survival of coho salmon in the ocean and the factors influencing their survival be given more attention in the future.

As noted previously, the deline in California hatchery coho returns may be an indication of poor ocean survival conditions.

The cyclical changes in oceanic and atmospheric conditions cannot be controlled by humans; however, protection is possible for fresh water habitats which are critical to short-term productivity and long-term survival of coho salmon populations.

E) <u>Climatic Factors</u>.

The decline of coho salmon in California has probably been exacerbated by natural climatic events. According to Brown et al. (in press), the droughts of 1976 - 1977 and 1986 - 1992 exacerbated existing poor habitat conditions, many streams dried-up completely and their production for those years was lost or severely curtailed. Drought conditions exacerbate existing problems in streams with degraded habitat. Payne and Associates (1989) found that access to lower Klamath River tributaries was blocked by large deltas that had been deposited since 1964 at the mouths of these streams. As a result of aggradation, several of these tributaries lack surface flow into the month of November during drought years.

From the winter of 1988 to 1992 there has been very low rainfall amounts in northern and central coastal California from October through December, the critical spawning time for chinook and coho salmon runs. Extremely low streamflows due to the drought restricted or prevented access to many streams and their tributaries for coho salmon spawners for almost a full life cycle (S. Downie, DFG, W. Jones, DFG, and T. Wooster, DFG, pers. comm.). In instances where coho were unable to gain access to preferred spawning tributaries, many fish were probably forced to spawn in mainstem river or stream habitats where the risk of mortality of eggs and alevins is very high due to streambed scour and poor condition of spawning gravels. Several coastal estuaries became lagoons that either never opened to the ocean or their opening was delayed much later in the year than normal. When this happens, it is difficult for adult coho salmon to enter into the stream system to spawn and when they do, they are forced to compete with other species also using the stream at that time (W. Jones, DFG and T. Wooster, DFG, pers. comm.). As a result of these drought caused conditions, Brown et al. (in press) speculate coho stocks in some streams may have been extirpated or temporarily eliminated, particularly when they considered that coho salmon in California apparently have a predominately 3-year life span for females.

Severe floods like the one in 1964 can move enormous volumes of sediment from unstable watersheds and landscapes disturbed by humans into and through river and stream systems. Kelsey (1980), CDWR (1982b) and Hagans et al. (1986) indicate high sediment loads can cause immediate and often long-lasting severe anadromous salmonid habitat degradation.

F) Ocean Fishing.

Since the passage of the Magneson Fishery Conservation and Management Act in 1976, both commercial and recreational ocean salmon fishing has been coordinated among the states of Washington, Oregon and California through the PFMC. This management process sets regulations within 200 miles of the shoreline, which is the principle area used by salmon, and establishes spawning escapement goals for salmon stocks. A general framework has been developed for managing coho salmon stocks south of Cape Falcon, in northern Oregon, as a stock aggregate. This stock aggregate, called the Oregon Coastal Natural Group, includes populations in northern and central California. Baker and Reynolds (1986) and Hassler (1987) report that most of the coho salmon caught off the coast of California originate in Oregon with northern California coho contributing only about 10 percent of the California catch.

Until 1993, coho salmon south of Cape Falcon were managed at harvest levels that were thought to be sustainable by natural populations which allowed about half the population to be harvested. In November, 1993, the PFMC adopted Amendment 11 to its 1985 Salmon Framework Plan that seeks to ensure spawning escapement in natural areas equivalent to 42 adult fish per mile of suitable stream habitat. This goal will reduce the harvest rate from about 50 percent to between 20 percent and 30 percent beginning in 1994. This will mean severely restricting or eliminating commercial coho salmon harvest if population levels remain as low as they have been since the late 1980's, as well as also restricting the ocean recreational coho salmon catch.

There is considerable disagreement between researchers, government agencies, timberland owners, commercial and recreational fishing interests, and various other user groups as to the role that fishing has played in the long-term decline of coho salmon populations. This disagreement continues even though there are few historical or recent records to indicate that curtailment of fishing has increased spawner abundance of coho salmon. As an example, curtailment of fishing seasons has been thought to have reduced harvest-related mortality rates on Oregon coastal coho salmon populations substantially during the past decade; however, there has been no evidence of a corresponding increase in coho spawner escapement during this period. Pearcy et al. (1992) believe this suggests that fishing curtailment is only keeping pace with continuing habitat deterioration and declining productivity of coho salmon populations.

Annual catch of coho salmon in California's commercial troll fishery ranged from 100,000 to more than 650,000 fish in the early 1960s to early 1970s (PFMC 1978). Massive increases in Oregon public and private hatchery production are believed to be the major factor resulting in the increased catches during this time period, but the commercial troll catch of coho salmon declined significantly in the late 1970s despite continued heavy plantings of hatchery fish. Because hatchery returns were either increasing or fluctuating nondirectionally at that time, Brown and Moyle (1991a) speculated wild coho stocks may have been providing a significant portion of the catch even as their populations were in decline.

During the period 1980 - 1990, annual commercial coho landings in California ports averaged 54,300 fish and annual recreational fishing produced an average of 29,300 fish (PFMC 1993). Aside from this harvest of coho salmon, which includes a mixture of hatchery and wild fish, there is incidental coho mortality during the chinook season and additional mortality is incurred in freshwater fisheries. The extent to which these additional mortalities may be affecting specific coho stocks or coho populations in general is unknown.

Spawning escapement of wild coho salmon populations in California is not well monitored and thus can not be directly considered in PFMC harvest decisions. The effects of directed fishing efforts through catch quotas and incidental fishing mortality on viability and distribution of coho salmon populations throughout the southern portion of their range is not well understood. Although California and southern Oregon populations of coho salmon are lumped with Oregon coastal populations by the PFMC for purposes of harvest management, Pearcy et al., (1992) believe these southern populations were not considered in the PFMC's assessment of over-fishing of Oregon coastal coho.

While over-fishing may not be the primary cause of decline of salmon stocks as a whole, as some wild coho populations reach extremely low levels, harvest may contribute to their continued decline and retard recovery. Consequently, problems can arise in "mixed stock" fisheries such as the ocean commercial and sport fisheries, where hatchery salmon stocks, which can sustain higher harvest rates, are harvested together with wild salmon stocks, which can sustain a maximum harvest rate well below that of hatchery fish. Where habitat conditions remain poor for wild coho salmon stocks, as they are in many north coast river and stream systems, they may be even less able to sustain harvest. As a general rule, when habitat conditions are favorable, depressed anadromous fish populations have the potential to rebound quickly. When habitat conditions are poor, anadromous fish can not survive in sufficiently large enough numbers to rebound quickly and consequently, fishing may become more of an impediment to population recovery.

Given that the quality of marine conditions and some freshwater habitats continue to decline or exhibit prolonged recovery, it may become more difficult to establish and enforce sustainable levels of coho salmon harvest. This concern apparently prompted the Humboldt Chapter of the American Fisheries Society (Fuller 1993), The National Audubon Society and other groups (Englemeyer 1993) to ask the PFMC for a closure of all ocean fishing during the 1993 season. The PFMC closed all commercial fishing for coho salmon south of Cape Falcon, Oregon, and allowed a greatly reduced recreational fishery quota of 68,000 fish in the same area, which translated to a harvest rate of 26 percent (PFMC 1993).

Reduced ocean harvest rate for coho off the Oregon and California coast can be expected at a result of the adoption of Amendment 11 to the PFMC's Salmon Framework Plan.

G) Other Concerns Regarding Factors Affecting Coho Salmon Populations.

There have been several other concerns expressed regarding factors affecting coho salmon populations in California.

Disease. The Pacific Northwest Fish Health Protection Committee (PNFHPC) (1989) believes anadromous stock transfers may carry diseases to which native populations do not have resistance. The introduction of disease into wild stocks is becoming an increasing concern, particularly with regard to bacterial kidney disease (BKD). The disease BKD is a chronic, slow developing disease caused by a pathogen (*Renibacterium salmoninarum*) and has been a major contributor to mortality of salmonids in some hatcheries. Iron Gate, Trinity River, Mad River and Warm Springs hatcheries and Noyo River and Big Creek coho stocks used for providing eggs for artificial propagation are known to harbor BKD. A detailed description of the effects of this disease on coho salmon and the various treatment programs being undertaken by the DFG to deal with this chronic disease can be found in Appendix D.

Hastein and Lindstad (1991) report there are a number of other virulent diseases that affect salmonids with the potential for transmission between hatchery and wild stocks. Steward and Bjornn (1990) could find little evidence for the importance of transmission of disease from hatchery to wild stocks, primarily because little work has been done, but they concluded the full impact of disease on supplemented stocks probably is underestimated.

Hybridization. Some researchers have recently expressed concern about hybridization between coho and fall-run chinook salmon stocks even though Chevassus (1979) reports natural hybridization between coho and chinook salmon is extremely rare and Blanc and Chevassus (1979) found deliberate attempts at artificial hybridization in hatcheries are usually not successful. Utter et al., (1989) reported no evidence of chinook-coho hybridization in a study of 86 chinook salmon populations spanning the area from British Columbia to California. Bartley et al., (1990) recently documented 2 instances of chinook-coho hybridization in the Klamath River basin and a third in the ocean fishery off of Eureka. In the first case, hybridization was likely a result of artificial blockage and crowding of large numbers of adult chinook and coho salmon in Deadwood Creek, a tributary just below Trinity River Hatchery. In the second case, hybridization was observed in samples of juvenile chinook salmon taken from rearing ponds at Camp Creek, a tributary to the Klamath River. Hybridization in this case presumably occurred due to inadvertent mixing of coho and chinook adults at the Iron Gate Hatchery where the adults taken from Camp Creek were spawned. These two instances of hybridization were the only two found out of the 36 chinook and 27 coho populations they examined.

In the third case, two large, hybrid salmon were found among a 1,000+ fish sample taken from the ocean commercial fishery. Both of the ocean recoveries were marked hatchery fish and it is highly likely these fish were the progeny of inadvertent mix-ups of coho and chinook salmon adults in a hatchery environment. One instance of hybridization has been observed in Hollow Tree Creek, a tributary to the South Fork Eel River (W. Jones, DFG, pers. comm.). The DFG does not believe that evidence exists to show hybridization poses a problem to coho salmon populations in California.

Coho population and habitat monitoring. Inadequate monitoring of wild coho salmon populations and trends in the health of their habitat is often cited by many researchers and government agency staff as a problem today. In California, there is no systematic, consistent, and coordinated approach to monitoring of wild coho escapement by state or federal agencies. Wild coho salmon in California are included in ocean harvests, but except for reductions in harvest rates overall, there has been no coordinated effort to determine the effects of these harvests and mitigate their potential adverse impacts to <u>specific</u> wild populations. Pearcy et al., (1992) did not consider California populations in their assessment of over-fishing of Oregon coastal coho.

Only very limited monitoring of freshwater wild coho salmon habitats has been done in the past but such efforts are increasing each year as the continuing decline of coho salmon stocks is brought to light and stream habitat restoration proposals are planned and ongoing (G. Flosi, DFG, and W. Jones, DFG, pers. comm.). In the past few years, there appears to be an expanding monitoring effort in the private sector which is very encouraging. Industrial timberland owners and others are obtaining the services of professional biologists to conduct stream habitat evaluations and surveys for presence, absence and abundance of coho salmon populations on their ownerships. The DFG hopes the results of these efforts are made available to us so we may expand the data necessary to cooperatively manage coho populations and fresh water habitats.

In California, there is very limited, albeit expanding, monitoring and regulation of artificial propagation programs for a variety of fish species that may directly or indirectly impact coho salmon populations. These artificial propagation programs are generally conducted on a large scale by the state and a smaller scale by a wide variety of volunteer organizations and individuals. Two north coast salmon rearing programs that have operated for nearly a decade will be discontinued this year and then closely monitored to see how well they worked in meeting desired salmon stock restoration goals (S. Downie, DFG, pers. comm.), while protecting genetic variability.

<u>Predation by wildlife and exotic species</u>. Numerous species of mammals and birds prey on anadromous salmonids at various stages of their life cycle. These species would include river otter, marine mammals such as sea lions and harbor seals, and various bird species such as cormorant, loon, merganser, gulls, heron, egret, and kingfisher. Anadromous salmonids evolved along with the host of predators that prey upon them. When salmon populations are healthy and robust, they can easily withstand a large degree of predation without ill effects at the population or individual stock level. However, when salmon populations become severely depressed as coho salmon are today, predation may retard recovery.

There are numerous reports and concerns expressed about predators, particularly marine mammals, taking salmon adults and juveniles from lowermost river reaches, estuaries, bays, lagoons and in the ocean at the mouths of rivers. As the hydrological regime of river and estuarine systems changes due to river flow, the vulnerability to predation of the salmonids living there may also change. When rivers are flowing high due to winter runoff, both adult and juvenile salmon can migrate quickly through the system and will be less vulnerable to predation. As river flows decrease, fish may become easier to find and their vulnerability to predation may increase. Droughts likely exacerbate this situation. This problem can become severe when a river system normally terminating in an estuary forms a sand barrier separating it from the ocean. This causes a lagoon to form that is a complete barrier to fish migration until river flows increase again and/or ocean wave and tidal influences remove the barrier. Juvenile salmon trapped inside and adults on the outside trying to get into these lagoons likely become more vulnerable to predation.

Bowlby (1981) studied pinniped predation on salmonids in the Klamath River estuary and found salmon to be only a minor part of the marine mammal's diet in that area. He found that sea lions fed primarily on Pacific lamprey (*Entosphenus tridentata*) and the majority of the sea lions vacated the estuary prior to the entry of salmon into the river. During the fall, he noted that the diet of harbor seals included only 6.2 percent salmonids during the period when adult salmon were present. Bowlby also notes marine mammal populations in general have not experienced accelerated, uncontrolled increases in recent years. However, recent antedotal observations indicate that sea lion populations may have doubled since Bowlby's estimates. Thus, it is not reasonable to believe marine mammal effects on salmon populations are of major concern even though marine mammals have been occasionally observed preying on both adult and juvenile salmonids.

In an attempt to provide new sport fishing opportunities, non-native fishes have been introduced into rivers throughout northwestern California in the last century but transplants did not usually survive. The DFG regulates introductions of non-native species in order to protect native species. The Sacramento squawfish (*Ptychocheilus grandis*) was recently, but illegally, introduced into the Eel River drainage and may be causing a problem for salmonids. Squawfish attain large size and eat smaller fish, including coho salmon juveniles, as they mature. The species has spread to most areas of the Eel River system in a little over a decade and is better adapted to warm water conditions in the mainstem Eel River during summer than are native salmonids. If the present trend in warming of main river channels is not reversed, squawfish populations can be expected to increase, as will their predation rate on salmonids.

(4) Habitat Availability and Trends That Include, But Are Not Limited to, an Assessment of the Following as Appropriate:

(A) Dependence on General Habitat Conditions Altered by Typical Forest Management Activities and Projected Time for Recovery.

Coho salmon require year-round cool, high quality water, an abundance of shade, heavy riparian canopy, deep pools, cover in the form of large, stable, woody debris and undercut banks, and an unembedded gravel/rubble substrate (Baker and Reynolds 1986). These habitat elements generally occur in coastal streams, larger river systems and their tributaries in heavily timbered watersheds.

Among other things, the FPRs were intended to be applied to protect watercourses and beneficial uses of water. In some streams, the existing FPRs are probably providing adequate protection for critical coho salmon habitat elements. However, monitoring programs are just now underway to determine rule effectiveness. In some sensitive streams, this level of protection has not been adequate, particularly in terms of the continued accumulation of sediment in spawning gravels, in filling of pools, increases in water temperature, loss of dense shade canopy, and non-recruitment of large, stable woody debris.

Logging practices prior to the rules have loaded many coho streams with sediment and many have not yet recovered. Due to existing degraded habitat, certain current harvesting practices can add significant additional direct or cumulative sources of sediment to streams. Puckett (1977) and Hofstra (1983) report many estuaries remain filled with sediment and debris washed in from upstream areas and are no longer capable of supporting the numbers of salmonid juveniles they once did. Dense shade canopy has been decreased and water temperatures raised when WLPZs and adjacent timber stands are harvested for the first time and by removal of additional overstory shade canopy each time subsequent harvesting within WLPZs occurs. Much of the large, stable woody debris historically found in many coho streams is no longer present because it has been either removed, flushed out of the system due to floods or buried deep within tons of sediment in highly aggraded streams.

In our review of streams, we have found critical habitat elements in some streams appear either fully recovered or well on their way to recovery; in other streams, recovery is many years away and for many streams recovery is somewhere in between. Recovery rates for degraded critical habitat elements in coho streams are quite variable depending on numerous watershed-wide as well as site-specific factors including underlying geology, precipitation amounts, presence of dams, degree of urbanization, past logging history and the type and degree of present land disturbances.

The recovery rates for fresh water habitats exhibiting problems from too much sediment will vary depending on the past ground disturbance, underlying geology of the watershed, total sediment in storage, present and future contributions of sediment, and stream gradient, morphology, and hydrology. However, the elimination or significant reduction of existing sediment discharges and prevention of future discharges of sediment to coho streams is essential to speed up the recovery rate. Streams with steeper gradients and high, flashy runoff

will flush sediment more quickly than flatter gradient streams and thus will recover faster. Estuaries exhibiting problems with too much sediment and debris may take additional decades to recover. However, minimizing sources of sediment and debris input from upstream areas will likely hasten the recovery rate in these areas as well.

Streams exhibiting problems with decreased dense shade canopy and increased water temperature will likely recover at a rate directly proportional to the degree of disturbance and continued activity within the WLPZs. Leaving WLPZs alone for several years, even for harvesting under emergency notices and exemptions, or developing effective special silvicultural recovery techniques, would be the most rapid method of recovery for these streams. Other less extreme approaches allowing some form of prescribed limited entry into WLPZs may also be possible without significantly retarding recovery rates.

Habitat recovery in streams lacking large woody debris will vary depending on the amount of large logs still remaining within or adjacent to the WLPZs and thus capable of reaching the active stream channel sometime in the future. Unfortunately, certain silvicultural methods, present harvesting practices and short rotation periods typically do not allow for the development and retention of old, large trees for recruitment of large woody debris. Large, old redwood trees, which take many decades to decay and thus provide very long-lived benefits to instream fishery habitats and overall stream and watershed stability, are particularly valuable and are difficult to replace. In streams where most of the previously existing large logs, trees and stumps have been removed, recovery could take many decades or more without direct intervention through a program to place large, stable wood into stream channels. Such a program would require the cooperation of private landowners and public agencies in order to succeed.

The Federal government recently recognized the need to allow streams to recover under Option 9 of President Clinton's Federal Forest Plan (1993). Option 9 delineated a system of key watersheds to serve as refugia that would be critical for maintaining and recovering at-risk stocks of anadromous salmonids, including coho salmon. These refugia include areas of good habitat as well as areas of degraded habitat. Areas in good condition would serve as anchors for the potential recovery of depressed stocks. Those of lower quality habitat are candidates for restoration and will become future sources of good habitat with the implementation of a comprehensive restoration program.

The identified network of key watersheds would apply only to Federal lands, some of which is checker-boarded with private commercial timberlands subject to the BOF FPRs. The Federal network includes Aquatic Conservation Emphasis Key Watersheds (Tier 1) that were selected specifically for directly contributing to anadromous salmonid conservation. All key watersheds and specific tributaries designated in California are Tier 1 watersheds emphasizing anadromous salmonid conservation. The streams and rivers in California included in the Tier 1 key watershed designation include the Smith River, Salmon River, Klamath River (Wooley, Elk, Dillon, Clear, Grider, Red Cap, Bluff, Blue and Camp creeks), Trinity River (North Fork and South Fork Trinity, New River, and Canyon and Horse Linto creeks), Mad River (Pilot Creek), Eel River (North Fork and Middle Fork Eel, Thatcher Creek and Black Butte River) and the Mattole River (Honeydew and Bear creeks).

Management emphasis on Federal lands in these designated key watersheds will be protection and restoration of anadromous salmonid stocks. The Federal government believes that this management direction will be an important factor when considering impacts of individual THPs or landscape level timber management plans on coho salmon in terms of cumulative impact analyses required under the FPRs.

(B) Dependence on Special Habitat Elements Adversely Impacted by Timber Operations.

Special habitat elements for coho include reasonably clean, unembedded spawning gravels, deep pools, cover in the form of large, stable, woody debris and undercut banks, heavy riparian shade canopy, and year-round cool water temperatures. These critical habitat elements are highly susceptible to the effects of timber harvest and have at one time been significantly adversely impacted in most streams historically supporting coho populations. Some coho streams have recovered from these past abuses better than others.

The DFG reviewed the available scientific literature and consulted various Fisheries experts and DFG field personnel during preparation of this petition to obtain information about the status of the habitat in various coho salmon streams within California. Examples of documented coho salmon streams where certain reaches, based on the evidence available at this time to the DFG, are believed to contain degraded coho critical habitat elements include the following. This list of streams is not intended to reflect in any way on current land management practices being conducted within their watersheds but instead is intended to merely point out what is known to us about these streams at this point in time. Monitoring programs are presently underway on some of these streams which may update this information. These streams are: South Fork Winchuck River; Wilson Creek; Mill Creek and Rowdy Creek (tributaries to the Smith River); McGarvey Creek, Ah Pah Creek, Turwar Creek, and Hunter Creek (tributaries to the Klamath River); Little River; Mill Creek, Lindsay Creek, North Fork Mad River, and Canyon Creek (tributaries to the Mad River); Salmon Creek, Elk River, and Freshwater Creek (tributaries to Humboldt Bay); Grizzly Creek, Yaeger Creek and Lawrence Creek (tributaries to the Van Duzen River); Sproul Creek and Redwood Creek (tributaries to the South Fork Eel River); the headwater tributaries of the Mattole River above the town of Whitehorn; Usal Creek; Juan Creek; Indian Creek (tributary to the Navarro River); Navarro River; Russian River; Garcia River; Gualala River; Waddell Creek; Scott Creek; and the San Lorenzo River and its tributary Pescadero Creek.

(C) Habitat Continuity and Juxtaposition Requirements as an Evaluation of Sensitivity to Habitat Fragmentation.

Coho salmon habitats and their dependent coho populations are relatively small and isolated, particularly in small coastal streams directly tributary to the ocean. According to Larkin (1981), Helle (1981) and Nehlsen et. al. (1991), adjacent populations continually exchange individuals, which helps minimize or prevent inbreeding depression or speciation, promotes a dynamic population structure, and is important in ensuring the future of the species and its role in the ecosystem. These authors also believe exchange of individuals from adjacent coho salmon populations also allows colonization and eventual repopulation of streams that lose their coho populations to natural events like prolonged drought or catastrophic events such as large landslides, flooding and wildfire.

Maintenance of a broad distributional range and an expansive network of connected populations is critical for the long-term survival of the species as a whole. Some researchers such as Frissell (1993), believe that large scale fragmentation and collapse of the coho salmon's range indicate that population structure and function is breaking down catastrophically, and that remaining isolated populations face greatly increased risk of extirpation.

(5) Suggested Feasible Protective Measures Required to Provide for Species Protection.

Not all coho salmon streams have the same level or type of current habitat degradation or recovery rate, so the development of feasible protective measures needs to be approached on a site-specific, case-by-case basis. There is good information about some streams in terms of their current habitat conditions and coho population status while little or nothing is known about others. Depending on the current status of individual streams, some streams may require additional protection over that afforded by the current FPRs while other streams may be adequately protected now.

Based on our current knowledge of coho salmon occurrence and abundance, there appear to be specific streams or stream reaches where coho populations are still present but may be potentially sensitive to any further habitat degradation. When these key streams or stream reaches are identified, assessments can be made of the present condition of coho salmon critical habitat elements occurring there as well as the status of the coho population using the habitat. Once these assessments are completed, site-specific protective measures can be developed when they are needed over and above the existing FPRs to ensure coho salmon populations occurring in the specific stream are adequately protected. The DFG anticipates that implementation of the sensitive watershed rules will provide a good mechanism for dealing with watershed-level analysis and solution of problems affecting coho salmon habitat and populations within California.

Because stream conditions are so variable, the DFG recommends that a consultation rule be established which also outlines THP information requirements and allows for landowner management plans.

(6) Other Information Specific to the Species Proposed That the Petitioner Believes to Be Relevant in Assisting the Board to Evaluate the Petition.

The DFG offers the following additional information that may be helpful to the BOF in evaluating this petition.

<u>It is the DFGs policy to protect individual salmonid populations.</u>

The maintenance of individual stocks is important to overall coho population health. The homing tendency of salmon leads to the evolution of individual and distinct races or "stocks" which develop specific adaptations to their native stream environments. The concept of stocks, which recognizes these distinct sub-populations, is widely accepted in fisheries management. Survival strategies and physical characteristics of fish within individual populations are flexible and respond to environmental cues but also have heritable components that are genetically based. Some examples of survival strategies and physical characteristics include the timing of their return to their natal stream, distance upriver to natal areas, gonad maturation rates, early life-history strategies, and timing of out-migration.

<u>Coho salmon life history information</u>.

Detailed information regarding the coho salmon's life history is provided in Appendix C for the BOF and others to use as a reference for anything they might wish to know about this species.

(7) Sources of Information Relied Upon to Complete the Petition.

A reference list of the sources of information specifically used and cited in preparing this petition, as well as additional information pertaining to coho salmon, can be found together in Appendix E and E1.

(8) Recommended Forest Practice Rules to Provide Guidance to Registered Professional Foresters (RPFs), Licensed Timber Operators (LTOs), Landowners and the Director on Species Protection.

California streams within the natural range of the coho salmon have experienced varying degrees of habitat damage from land use practices and have recovered at different rates depending on the type and extent of damage. Properly applied BOF FPRs will probably be sufficient to prevent additional damage or not impede recovery in most situations. In some situations special practices may be required. In order to determine which watercourses require additional or different protection than provided by the FPRs, the DFG recommends a modified consultation procedure be followed based on the following guidelines.

The CDFs Director's representative should request consultation by a designated DFG biologist from the appropriate DFG regional manager when the following conditions exist:

1. *Whenever the California or Federal endangered species acts apply.*

2. *If history of substantial coho habitat damage exists.*

3. *Where there has been a substantial documented decline in historical coho populations.*

4. *If a THP or any timber operation has significant potential for further habitat degradation as determined by CDF or the THP review team.*

Consultation with the DFG shall be considered complete when any one of the following documents apply to the THP or timber operation being considered:

1. *A sensitive watershed plan promulgated by the BOF is in existence*

which specifically and adequately protects coho salmon habitat and life history requirements.

2. *A consultation document signed by the appropriate DFG regional manager has been completed which applies to a larger area of coho habitat and includes the proposed THP or timber operation.*

3. *A site-specific consultation signed by the DFG designated biologist has been completed for the proposed THP or timber operation.*

4. *A cooperative agreement with DFG and the landowner which includes protective measures or restoration projects.*

If a site-specific consultation is necessary, the DFG consultation shall include:

1. *A written description of the specific life history requirement of coho salmon in the watercourse which needs protection exceeding those in the existing FPRs or the mitigations proposed in the THP.*

2. *Written findings describing whether the existing FPRs and special THP mitigation measures will protect, enhance or degrade existing coho habitat conditions and life history requirements.*

3. *Written recommendations as necessary to provide further protection measures reducing potential damage to below the level of significance.*

Whenever a site-specific THP consultation is necessary with the DFG, the RPF shall include the following information in the THP:

1. *Available historical information as well as any recent information collected by the RPF or landowner regarding stream channel conditions depicting the current condition of critical coho habitat elements in the area at risk from THP operations.*

2. *An assessment of those habitat elements in CCR 916.4b presently found in the area at risk from THP operations.*

3. *An assessment of how those features described in CCR 916.4b will be protected during and following timber operations. The RPF shall focus particularly on the risks from increased sedimentation, loss of thermal protection and dense shade canopy, and loss of large, stable*

woody debris and their recruitment.

Following timber operations, the CDF shall conduct at least one inspection and shall on every inspection ensure that all mitigation measures and BOF rules have compliance and are effective in protecting features found in CCR 916.4b or described in the consultation document. The completion report shall not be signed as final until all coho protection measures have been completed and are determined to be effective. Focus shall be particularly on sedimentation, loss of thermal protection and dense shade canopy, and loss of large, stable woody debris and their recruitment caused by timber operations.

The CDF inspector shall forward to the DFG the findings of the postharvest inspection, necessary corrective actions required or taken, and a statement that the mitigation measures or any corrective actions taken are effective. These findings shall also be posted with the THP record.

(9) The Potential Economic Impacts of Classifying a Species Sensitive.

Coho salmon are important to a varied California economy, particularly on the north coast. Commercial salmon fishermen have historically depended on coho salmon for a portion of their income, sustaining the viability of commercial fishing as an occupation. Shore-based businesses likewise depend on a viable and stable fishery for a portion of their income. The coastal economy as a whole derives between 10 and 100 million dollars annually from commercial salmon fishing, depending on stock abundance levels (PFMC 1993).

The California north coast recreational salmon industry is more heavily dependent on coho salmon than the commercial industry, since coho salmon are generally more accessible (close to shore) than chinook salmon. From Fort Bragg north, coho generally make up over half the total salmon catch and support local economies that depend on fishing.

The continued loss of local populations of coho salmon will result in continuing declines in the number of fish caught annually in both the sport and commercial fishery and the loss of direct and indirect economic benefits during the time period it takes for coho salmon populations to recover. Declines in coho salmon populations and subsequent reductions in the sport and commercial fishery can equate to significant unknown losses of dollars for local economies dependent on fishing. In response to continuing declines in coho salmon populations, the ocean catch rate for coho has been progressively and significantly reduced since 1987. Unfortunately, the expected corresponding increases in the number of coho returning to coastal rivers and streams to spawn have not yet occurred.

Any additional protection afforded to coho salmon habitat as a result of coho being listed as a sensitive species will likely have additional side benefits to chinook salmon, steelhead trout and coastal cutthroat trout populations. Such benefits would accrue to these other fish species because their populations and habitat requirements overlap that of coho salmon to a large degree. Any increases in populations of these other species should equate to a potentially significant benefit to local economies in areas where they are sought in the commercial or sport fishery.

If coho salmon are listed as a sensitive species, the economic impacts to California's forest based economy will be minimal in watersheds where it can be demonstrated that existing FPRs are effective in protecting instream habitats. Costs may be substantial in watersheds that have been severely disrupted by past logging practices, are not recovering well, and where proposed operations will further degrade habitat or delay recovery.

TABLE 1

List of streams historically known to produce coho salmon. Type of evidence (SS = stream survey, FR = fish rescue operation, CC = carcass count, AT = adult trap, JT = juvenile trap, LIT = literature search, OT = other), and source. Streams were listed as they occur on the California coast from north to south. Only the most recent field sighting was included. Compilations of file reports and personal communications were only cited when no other source was available. Numbers of fish sighted are described in Appendix B and B-1. Hatchery returns are not included. Sources followed by an asterisk were obtained from the Preserve Design Diversity Database (1989) maintained at U.C. Davis by Peter Moyle, rather than directly from the source listed. This entire table comes from Brown and Moyle (1991a).

Drainage	Stream	Method	Source
SF Winchuck River	SF Winchuck River	FR	Shapovalov 1940
Illinois River			
WF Illinois River	Broken Kettle Creek	LIT	Hassler 1988
WF Illinois River	Elk Creek	LIT	Hassler 1988
EF Illinois River	Dunn Creek	SS	P. Moyle, unpubl. data
Smith River	Smith River	LIT	Hassler 1988
	Rowdy Creek	FR	Kimsey 1953
Rowdy Creek	Dominic Creek	LIT	Hassler 1988
Rowdy Creek	Savoy Creek	LIT	Hassler 1989
Rowdy Creek	Copper Creek	LIT	Hassler 1988
	Morrison Creek	FR	Kimsey 1953
	Jaqua Creek	OT	Hallock et al. 1952
	Mill Creek	OT	Hallock et al. 1952
Mill Creek	EF Mill Creek	LIT	Hassler 1988
Mill Creek	WF Mill Creek	LIT	Hassler 1988
Mill Creek	Bummer Lake Creek	SS	Burns 1971
	MF Smith River	LIT	Hassler 1988
MF Smith River	Hardscrabble Creek	LIT	Hassler 1988
MF Smith River	Myrtle Creek	LIT	Hassler 1988
MF Smith River	NF Smith River	LIT	Hassler 1988
NF Smith River	Peridotite Creek	LIT	Hassler 1988
NF Smith River	Still Creek	LIT	Hassler 1988
NF Smith River	Diamond Creek	LIT	Hassler 1988
MF Smith River	Eighteen Mile Creek	LIT	Hassler 1988

MF Smith River	Patrick Creek	LIT	Hassler 1988
Patrick Creek	Twelve Mile Creek	LIT	Hassler 1988
Patrick Creek	Shelly Creek	LIT	Hassler 1988
Patrick Creek	Eleven Mile Creek	LIT	Hassler 1988
Patrick Creek	Ten Mile Creek	LIT	Hassler 1988
Patrick Creek	WF Patrick Creek	LIT	Hassler 1988
MF Smith River	Monkey Creek	LIT	Hassler 1988
MF Smith River	Siskiyou Fork	LIT	Hassler 1988
MF Smith River	Packsaddle Creek	LIT	Hassler 1988
MF Smith River	Griffin Creek	LIT	Hassler 1988
MF Smith River	Knopki Creek	LIT	Hassler 1988
	SF Smith River	LIT	Hassler 1988
SF Smith River	Craigs Creek	LIT	Hassler 1988
SF Smith River	Coon Creek	LIT	Hassler 1988
SF Smith River	Hurdy Gurdy Creek	SS	P. Moyle, unpubl. data
SF Smith River	Jones Creek	LIT	Hassler 1988
Jones Creek	Muzzle Loader Creek	LIT	Hassler 1988
SF Smith River	Buck Creek	LIT	Hassler 1988
SF Smith River	Quartz Creek	LIT	Hassler 1988
SF Smith River	Eight Mile Creek	LIT	Hassler 1988
Eight Mile Creek	Williams Creek	LIT	Hassler 1988
SF Smith River	Prescott Fork	LIT	Hassler 1988
Coastal (Lake Earl)	Jordan Creek	OT	Hallock et al.1952
Coastal (Lake Earl)	Yonkers Creek	LIT	Hassler 1988
Coastal	Elk Creek	LIT	Hassler 1988
Coastal	Wilson Creek	FR	Kimsey 1953
Klamath River	Estuary	OT	Gibbs and Kimsey 1955
	Hunter Creek	FR	Kimsey 1953
Hunter Creek	Salt Creek	LIT	Hassler 1988
Salt Creek	High Prairie Creek	FR	Kimsey 1953
Hunter Creek	Mynot Creek	FR	Kimsey 1953
	Richardson Creek	LIT	Hassler 1988
	Saugep Creek	LIT	Hassler 1988
	Waukell Creek	LIT	Hassler 1988
	Hoppaw Creek	FR	Kimsey 1953
	Turwar Creek	FR	Kimsey 1953
	McGarvey Creek	OT	Hallock et al.1952
	Tarup Creek	LIT	Hassler 1988
	Omagar Creek	LIT	Hassler 1988
	Blue Creek	LIT	Hassler 1988

Table 1. continued

Drainage	Stream	Method	Source
Blue Creek	WF Blue Creek	LIT	Hassler 1988
Blue Creek	Nickowitz Creek	LIT	Hassler 1988
Blue Creek	Crescent City Fork	LIT	Hassler 1988
	Ah Pah Creek	LIT	Hassler 1988
Ah Pah Creek	SF Ah Pah Creek	SS	D. McCleod, unpubl. data
	Bear Creek	LIT	Hassler 1988
	Tectah Creek	LIT	Hassler 1988
	Pecwan Creek	LIT	Hassler 1988
	Mettah Creek	LIT	Hassler 1988
	Roach Creek	LIT	Hassler 1988
	Miner's Creek	LIT	Hassler 1988
	Pine Creek	LIT	Hassler 1988
Pine Creek	Little Pine Creek	LIT	Hassler 1988
	Bluff Creek	LIT	Hassler 1988
	Slate Creek	LIT	Hassler 1988
	Red Cap Creek	LIT	Hassler 1988
	Boise Creek	LIT	Hassler 1988
	Irving Creek	SS	A. Olson, unpubl. data
	Camp Creek	LIT	Hassler 1988
	Dillon Creek	LIT	Hassler 1988
	Ukonom Creek	LIT	Hassler 1988
	Independence Creek	SS	A. Olson, unpubl. data
	Clear Creek	LIT	Hassler 1988
	Elk Creek	LIT	Hassler 1988
Elk Creek	EF Elk Creek	SS	A. Olson, unpubl. data
	Indian Creek	LIT	Hassler 1988
Indian Creek	SF Indian Creek	LIT	Hassler 1988
Indian Creek	EF Indian Creek	LIT	A. Olson, unpubl. data
Indian Creek	Mill Creek	SS	A. Olson, unpubl. data
	China Creek	SS	D. Maria, unpubl.

Table 1. continued

Drainage	Stream	Method	Source
			data*
	Thompson Creek	LIT	Hassler 1988
	Seiad Creek	LIT	Hassler 1988
	Grider Creek	SS	D. Maria, unpubl. data*
Grider Creek	West Grider Creek	LIT	Hassler 1988
	Horse Creek	LIT	Hassler 1988
Horse Creek	Buckhorn Creek	LIT	Hassler 1988
Horse Creek	Middle Creek	LIT	Hassler 1988
Horse Creek	Salt Gulch	LIT	Hassler 1988
	Barkhouse Creek	LIT	Hassler 1988
	Beaver Creek	LIT	D. Maria, unpubl. data*
	Humbug Creek	LIT	Hassler 1988
	Cottonwood Creek	LIT	Hassler 1988
	Shasta River	LIT	Hassler 1988
Shasta River	Big Springs Creek	LIT	Hassler 1988
	Willow Creek	LIT	Hassler 1988
	Bogus Creek	LIT	Hassler 1988
	Shasta River	AT	Coots 1958
	Klamathon Racks	AT	Bryant 1937
	Fall Creek	OT	Coots 1957
Trinity River	Trinity River	LIT	Hassler 1988
(trib. to Klamath	Scottish Creek	LIT	Hassler 1988
River)	Mill Creek	LIT	Hassler 1988
	Hostler Creek	LIT	Hassler 1988
	Supply Creek	LIT	Hassler 1988
	Campbell Creek	LIT	Hassler 1988
	Tish Tang A Tang C	LIT	Hassler 1988
	Horse Linto Creek	SS	P. Moyle, unpubl. data
	Willow Creek	LIT	Hassler 1988
	SF Trinity River	LIT	Hassler 1988
SF Trinity River	Eltapom Creek	LIT	Hassler 1988
SF Trinity River	Pelletreu Creek	LIT	Hassler 1988
SF Trinity River	Hayfork Creek	LIT	Hassler 1988
Hayfork Creek	Olsen Creek	LIT	Hassler 1988

Table 1. continued

Drainage	Stream	Method	Source
SF Trinity River	Butter Creek	LIT	Hassler 1988
SF Trinity River	Rattlesnake Creek	LIT	Hassler 1988
	New River	LIT	Hassler 1988
	Manzanita Creek	LIT	Hassler 1988
	NF Trinity River	LIT	Hassler 1988
EF NF Trinity R.	Indian Creek	LIT	Hassler 1988
	Canyon Creek	LIT	Hassler 1988
	Browns Creek	LIT	Hassler 1988
	Rush Creek	SS	D. Painter, pers. comm.*
	Deadwood Creek	LIT	Hassler 1988
Salmon River	Salmon River	LIT	Hassler 1988
(trib. to Klamath	Wooley Creek	LIT	Hassler 1988
River)	Nordheimer Creek	LIT	Hassler 1988
	NF Salmon River	LIT	Hassler 1988
NF Salmon River	North Russian Cr.	LIT	Hassler 1988
NF Salmon River	South Russian Cr.	LIT	Hassler 1988
	SF Salmon River	LIT	Hassler 1988
SF Salmon River	Knownothing Creek	LIT	Hassler 1988
SF Salmon River	Methodist Creek	LIT	Hassler 1988
SF Salmon River	EF SF Salmon River	SS	D. Maria, pers. comm.*
EF SF Salmon R.	Taylor Creek	LIT	Hassler 1988
Scott River	Tomkins Creek	LIT	Hassler 1988
(trib. to Klamath	Kelsey Creek	LIT	Hassler 1988
River)	Canyon Creek	LIT	Hassler 1988
	Shackleford Creek	LIT	Hassler 1988
Shackleford Creek	Mill Creek	LIT	Hassler 1988
	Kidder Creek	LIT	Hassler 1988
Kidder Creek	Patterson Creek	LIT	Hassler 1988
	Etna Creek	LIT	Hassler 1988
	French Creek	LIT	Hassler 1988
French Creek	Miners Creek	LIT	Hassler 1988
	Sugar Creek	LIT	Hassler 1988
	EF Scott River	LIT	Hassler 1988
EF Scott River	Big Mill Creek	LIT	Hassler 1988
	SF Scott River	LIT	Hassler 1988

Table 1. continued

Drainage	Stream	Method	Source
Redwood Creek	Redwood Creek	FR	Kimsey 1953
	Prairie Creek	FR	Kimsey 1952
Prairie Creek	Little Lost Man Cr.	OT	Hallock et al. 1952
Prairie Creek	Lost Man Creek	OT	Hallock et al. 1952
Prairie Creek	May Creek	OT	Hallock et al. 1952
Prairie Creek	Godwood Creek	SS	Burns 1971
Prairie Creek	Boyes Creek	OT	Hallock et al. 1952
Prairie Creek	Browns Creek	LIT	Hassler 1988
Prairie Creek	Streelow Creek	LIT	Hassler 1988
	Tom McDonald Creek	LIT	Hassler 1988
	Bridge Creek	LIT	Hassler 1988
	Coyote Creek	LIT	Hassler 1988
	Panther Creek	LIT	Hassler 1988
	Lacks Creek	LIT	Hassler 1988
Big Lagoon	Big Lagoon	OT	Bailey and Kimsey 1952
Stone Lagoon	McDonald Creek	FR	Kimsey 1953
	Fresh Creek	LIT	Hassler 1988
Little River	Little River	OT	Hallock et al. 1952
	SF Little River	LIT	Hassler 1988
SF Little River	Lower SF Little R.	LIT	Hassler 1988
SF Little River	Upper SF Little R.	LIT	Hassler 1988
Coastal	Strawberry Creek	LIT	Hassler 1988
Mad River	Mad River	FR	Kimsey 1952
	Warren Creek	LIT	Hassler 1988
	Lindsay Creek	OT	Hallock et al. 1952
Lindsay Creek	Squaw Creek	FR	Kimsey 1953
Lindsay Creek	Grassy Creek	OT	Hallock et al. 1952
Lindsay Creek	Mather Creek	LIT	Hassler 1988
	Hall Creek	LIT	Hassler 1988
Hall Creek	Mill Creek	LIT	Hassler 1988
Hall Creek	Noisy Creek	OT	Hallock et al. 1952
	Camp Bauer Creek	OT	Hallock et al. 1952
	Leggit Creek	LIT	Hassler 1988
Leggit Creek	Kelly Creek	LIT	Hassler 1988

Table 1. continued

Drainage	Stream	Method	Source
	Powers Creek	LIT	Hassler 1988
	Quarry Creek	LIT	Hassler 1988
Quarry Creek	Palmer Creek	LIT	Hassler 1988
	NF Mad River	FR	Shapovalov 1940
NF Mad River	Sullivan Creek	LIT	Hassler 1988
NF Mad River	Long Prairie Creek	LIT	Hassler 1988
	Dry Creek	LIT	Hassler 1988
	Cañon Creek	SS	L. Preston, unpubl. data
	Maple Creek	LIT	Hassler 1988
	Black Creek	LIT	Hassler 1988
	Boulder Creek	LIT	Hassler 1988
Humboldt Bay	Janes Creek	OT	Hull 1987
	Jolly Giant Creek	OT	Hull 1987
	Jacoby Creek	OT	Hull 1987
	Rocky Gulch Creek	LIT	Hassler 1988
	Cochran Creek	OT	Hull 1987
	Freshwater Creek	OT	Hull 1987
Freshwater Creek	Ryan Creek	LIT	Hassler 1988
Freshwater Creek	McCready Gulch	LIT	Hassler 1988
Freshwater Creek	Little Freshwater C	LIT	Hassler 1988
Freshwater Creek	Cloney Gulch	LIT	Hassler 1988
Cloney Gulch	Falls Gulch	LIT	Hassler 1988
Freshwater Creek	Graham Gulch	LIT	Hassler 1988
	Martin Slough	LIT	Hassler 1988
	Elk River	OT	Hallock et al. 1952
Elk River	NF Elk River	LIT	Hassler 1988
Elk River	SF Elk River	LIT	Hassler 1988
SF Elk River	Little SF Elk River	LIT	Hassler 1988
	College of Redwoods Creek	LIT	Hassler 1988
	Salmon Creek	LIT	Hassler 1988
Eel River	estuary	OT	Puckett 1977
	below Van Duzen R.	OT	Murphy and DeWitt 1951
	Salt River	SS	Mills 1983
Salt River	Russ Creek	LIT	Hassler 1988

Table 1. continued

Drainage	Stream	Method	Source
Salt River	Reas Creek	SS	Mills 1983
	Rohner Creek	SS	Mills 1983
	Price Creek	FR	Shapovalov 1941
	Howe Creek	SS	Mills 1983
Howe Creek	Atwell Creek	SS	Mills 1983
	Dinner Creek	FR	Shapovalov 1940
	Jordan Creek	OT	Hallock et al. 1952
Eel River	near Pepperwood	FR	Shapovalov 1940
	Shively Creek	SS	Mills 1983
	Bear Creek	CC	G. Flosi, unpubl. data
	Chadd Creek	CC	G. Flosi, unpubl. data
	Larabee Creek	SS	Mills 1983
Larabee Creek	Carson Creek	CC	G. Flosi, unpubl. data
	Newman Creek	FR	Shapovalov 1940
	Jewett Creek	SS	Mills 1983
	Kekawaka Creek	LIT	Hassler 1988
	Outlet Creek	CC	G. Flosi, unpubl. data
Outlet Creek	Bloody Run Creek	SS	W. Jones, pers. comm.
Outlet Creek	Long Valley Creek	CC	Brown and Moyle 1991
Outlet Creek	Reeves Canyon Creek	CC	G. Flosi, unpubl. data
Outlet Creek	Ryan Creek	CC	G. Flosi, unpubl. data
Outlet Creek	Rowes Creek	SS	W. Jones, pers. comm.
Outlet Creek	Mill Creek	SS	W. Jones, pers. comm.
Mill Creek	Willits Creek	CC	G. Flosi, unpubl. data
Willits Creek	Dutch Henry Creek	SS	W. Jones, pers. comm.

Table 1. continued

Drainage	Stream	Method	Source
Outlet Creek	Broaddus Creek	CC	G. Flosi, unpubl. data
Outlet Creek	Haehl Creek	CC	G. Flosi, unpubl. data
Outlet Creek	Baechtel Creek	CC	G. Flosi, unpubl. data
	Indian Creek	SS	Mills 1983
Tomki Creek	Rocktree Creek	SS	Mills 1983
Tomki Creek	String Creek	SS	Mills 1983
Tomki Creek	Tarter Creek	SS	Mills 1983
Van Duzen River	Van Duzen River	SS	Brown and Moyle 1991
(trib. to Eel River)	Palmer Creek	OT	Hallock et al. 1952
	Wolverton Gulch	SS	Mills 1983
	Yaeger Creek	SS	Mills 1983
Yaeger Creek	Cooper Mill Creek	OT	Hallock et al. 1952
Yaeger Creek	Wilson Creek	SS	Mills 1983
Yaeger Creek	Lawrence Creek	CC	G. Flosi, unpubl. data
Lawrence Creek	Shaw Creek	CC	G. Flosi, unpubl. data
	Cuddeback Creek	FR	Shapovalov 1941
	Fielder Creek	OT	Hallock et al. 1952
	Cummings Creek	SS	Brown and Moyle 1991
	Hely Creek	OT	Hallock et al. 1952
	Root Creek	LIT	Hassler 1988
	Grizzly Creek	OT	Hallock et al. 1952
Grizzly Creek	Stevens Creek	LIT	Hassler 1988
	Hoaglund Creek	LIT	Hassler 1988
	Little Larabee Cr.	LIT	Hassler 1988
South Fork Eel River	SF Eel River	SS	Nielsen et al. 1991
(trib. to Eel River)	Bull Creek	JT	S. Downie, unpubl. data
Bull Creek	Squaw Creek	CC	G. Flosi, unpubl. data

Table 1. continued

Drainage	Stream	Method	Source
Bull Creek	Albee Creek	LIT	Hassler 1988
Bull Creek	Mill Creek	LIT	Hassler 1988
	Canoe Creek	SS	Brown and Moyle 1991
	Bridges Creek	FR	Shapovalov 1941
	Elk Creek	FR	Shapovalov 1940
	Salmon Creek	FR	Shapovalov 1940
	Bear Butte Creek	FR	Shapovalov 1940
	Fish Creek	FR	Shapovalov 1940
	Anderson Creek	CC	G. Flosi, unpubl. data
	Dean Creek	FR	Shapovalov 1940
	Redwood Creek	JT	S. Downie, unpubl. data
Redwood Creek	Seely Creek	SS	Mills 1983
Redwood Creek	Miller Creek	SS	Mills 1983
Redwood Creek	China Creek	SS	Mills 1983
Redwood Creek	Dinner Creek	SS	Mills 1983
	Sprowel Creek	SS	L. Brown, pers. obs.
Sprowel Creek	Warden Creek	LIT	Hassler 1988
Sprowel Creek	Little Sprowel Cr.	LIT	L. Brown, pers. obs.
Sprowel Creek	WF Sprowel Creek	LIT	Hassler 1988
	EB SF Eel River	JT	S. Downie, unpubl. data
EB SF Eel River	Squaw Creek	SS	Mills 1983
	Durphy Creek	FR	Shapovalov 1941
	Milk Ranch Creek	SS	Mills 1983
	Low Gap Creek	SS	Mills 1983
	Indian Creek	CC	Nielsen et al. 1991
	Piercy Creek	CC	Nielsen et al. 1991
	Standley Creek	SS	Mills 1983
	McCoy Creek	SS	Mills 1983
	Bear Pen Creek	SS	Mills 1983
Bear Pen Creek	Cub Creek	SS	Mills 1983

Table 1. continued

Drainage	Stream	Method	Source
	Red Mountain Creek	SS	Mills 1983
	Wildcat Creek	SS	Mills 1983
	Hollowtree Creek	CC	Nielsen et al. 1991
Hollowtree Creek	Mule Creek	SS	Mills 1983
Hollowtree Creek	Walters Creek	LIT	Hassler 1988
Hollowtree Creek	Redwood Creek	CC	Nielsen et al. 1991
Hollowtree Creek	Bond Creek	LIT	Hassler 1988
Hollowtree Creek	Michaels Creek	SS	Nielsen et al. 1991
Hollowtree Creek	Waldron Creek	SS	Mills 1983
Hollowtree Creek	Huckleberry Creek	SS	Nielsen et al. 1991
Hollowtree Creek	Butler Creek	SS	Nielsen et al. 1991
	Cedar Creek	LIT	Nielsen et al. 1991
	Rattlesnake Creek	SS	Mills 1983
Rattlesnake Creek	Cummings Creek	SS	P. Baker, pers. comm.*
	Ten Mile Creek	CC	G. Flosi, unpubl. data
Ten Mile Creek	Grub Creek	SS	Mills 1983
Ten Mile Creek	Streeter Creek	CC	G. Flosi, unpubl. data
Ten Mile Creek	Big Rock Creek	SS	Mills 1983
Ten Mile Creek	Mud Springs Creek	SS	Mills 1983
Ten Mile Creek	Mill Creek	SS	Mills 1983
Ten Mile Creek	Cahto Creek	SS	Mills 1983
	Fox Creek	SS	Mills 1983
	Elder Creek	SS	Brown and Moyle 1991
	Jack of Hearts Cr.	CC	Nielsen et al. 1991
	Deer Creek	SS	Mills 1983
	Little Charlie Cr.	LIT	Hassler 1983
	Dutch Charlie Creek	CC	G. Flosi, unpubl. data
	Redwood Creek	CC	Nielsen et al. 1991
	Kenny Creek	SS	Mills 1983
	Haun Creek	LIT	Hassler 1983
	Rock Creek	SS	Mills 1983
	Bear Creek	SS	Mills 1983

Table 1. continued

Drainage	Stream	Method	Source
	Taylor Creek	SS	Mills 1983
Middle Fork Eel River	MF Eel River	LIT	Hassler 1988
(trib. to Eel River)	Mill Creek	SS	Mills 1983
Mill Creek	Grist Creek	SS	Mills 1983
	Rattlesnake Creek	SS	Mills 1983
NF of MF Eel River	Rock Creek	SS	Mills 1983
North Fork Eel River (trib. to Eel River)	Bluff Creek	SS	Mills 1983
Coastal	Guthrie Creek	LIT	Hassler 1988
Bear River	Bear River	LIT	Hassler 1988
	Bonanza Gulch	LIT	Hassler 1988
	SF Bear Creek	LIT	Hassler 1988
SF Bear Creek	Hollister Creek	LIT	Hassler 1988
Coastal	McNut Gulch	LIT	Hassler 1988
Mattole River	Mattole River	LIT	G. Peterson pers.
	NF Mattole River	LIT	Hassler 1988
	Mill Cr. (Petrolia)	LIT	Hassler 1988
	Clear Creek	LIT	Hassler 1988
	Conklin Creek	LIT	Hassler 1988
	McGinnis Creek	LIT	Hassler 1988
	Indian Creek	LIT	Hassler 1988
	Squaw Creek	LIT	Hassler 1988
	Pritchard Creek	LIT	Hassler 1988
	Granny Creek	LIT	Hassler 1988
	Saunders Creek	LIT	Hassler 1988
	Woods Creek	LIT	Hassler 1988
	Upper NF Mattole R.	LIT	Hassler 1988
			comm.
Upper NF Mattole R	Rattlesnake Creek	LIT	Hassler 1988
Upper NF Mattole R	Oil Creek	LIT	Hassler 1988
Oil Creek	Devils Creek	LIT	Hassler 1988

Table 1. continued

Drainage	Stream	Method	Source
	Honeydew Creek	LIT	Hassler 1988
Honeydew Creek	Bear Trap Creek	LIT	Hassler 1988
	Dry Creek	LIT	Hassler 1988
	Middle Creek	LIT	Hassler 1988
	Westlund Creek	LIT	Hassler 1988
	Gilham Creek	LIT	Hassler 1988
	Fourmile Creek	LIT	Hassler 1988
	Sholes Creek	LIT	Hassler 1988
	Marrow Creek	LIT	Hassler 1988
	Grindstone Creek	LIT	Hassler 1988
	Mattole Canyon	LIT	Hassler 1988
	Blue Slide Creek	LIT	Hassler 1988
	Bear Creek	LIT	Hassler 1988
Bear Creek	SF Bear Creek	SS	L. Preston, unpubl. data
	Big Finley Creek	LIT	Hassler 1988
	Eubank Creek	LIT	Hassler 1988
	Bridge Creek	LIT	Hassler 1988
	McKee Creek	LIT	Hassler 1988
	Vanbankin Creek	LIT	Hassler 1988
	Mill Creek	LIT	Hassler 1988
	Baker Creek	LIT	Hassler 1988
	Thompson Creek	LIT	Hassler 1988
Coastal	Whale Gulch Creek	OT	Sommerstrom 1984
Coastal	Indian Creek	OT	Murphy 1950
Coastal	Jackass Creek	OT	Sommerstrom 1984
Coastal	Usal Creek	FR	Kimsey 1953
Cottoneva Creek	Cottoneva Creek	OT	Sommerstrom 1984
	SF Cottoneva Creek	LIT	Hassler 1988
	NF Cottoneva Creek	LIT	Hassler 1988
Coastal	Hardy Creek	OT	Sommerstrom 1984

Table 1. continued

Drainage	Stream	Method	Source
Coastal	Juan Creek	OT	Sommerstrom 1984
	Little Juan Creek	LIT	Hassler 1988
Coastal	Howard Creek	SS	T. Taylor, unpubl. data*
Coastal	DeHaven Creek	OT	Murphy 1950
Coastal	Wages Creek	OT	Sommerstrom 1984
Ten Mile River	Ten Mile River	OT	Sommerstrom 1984
	NF Ten Mile River	LIT	Hassler 1988
NF Ten Mile River	Mill Creek	LIT	Hassler 1988
NF Ten Mile River	Little NF Ten Mile	LIT	Hassler 1988
	SF Ten Mile River	LIT	Hassler 1988
SF Ten Mile River	Smith Creek	LIT	Hassler 1988
SF Ten Mile River	Campbell Creek	LIT	Hassler 1988
SF Ten Mile River	Churchman's Creek	LIT	Hassler 1988
SF Ten Mile River	Redwood Creek	CC	Nielsen et al. 1991
	MF Ten Mile River	LIT	Hassler 1988
MF Ten Mile River	Bear Haven Creek	LIT	Hassler 1988
Pudding Creek	Pudding Creek	CC	Nielsen et al. 1991
	Little Valley Creek	LIT	Hassler 1988
Noyo River	Noyo River	CC	Nielsen et al. 1991
	SF Noyo River	LIT	Nielsen et al. 1991
SF Noyo River	Kass Creek	LIT	Nielsen et al. 1991
SF Noyo River	NF SF Noyo River	CC	Nielsen et al. 1991
SF Noyo River	Parlin Creek	CC	Nielsen et al. 1991
	Little NF Noyo R.	SS	Burns 1971
	Duffy Gulch	LIT	Hassler 1988
	NF Noyo River	LIT	Hassler 1988
NF Noyo River	Marble Gulch	LIT	Hassler 1988
NF Noyo River	Haysworth Creek	LIT	Hassler 1988
NF Noyo River	MF NF Noyo River	LIT	Hassler 1988
	Olds Creek	LIT	Hassler 1988
	Redwood Creek	LIT	Hassler 1988
Hare Creek			

Table 1. continued

Drainage	Stream	Method	Source
Hare Creek	SF Hare Creek	LIT	Hassler 1988
	Bunker Gulch Creek	LIT	Hassler 1988
Coastal	Jug Handle Creek	SS	T. Taylor, unpubl. data*
Caspar Creek	SF Caspar Creek	CC	Nielsen et al. 1991
	NF Caspar Creek	SS	Nielsen et al. 1991
CoastaL	Doyle Creek	LIT	Hassler 1988
Coastal	Russian Gulch	OT	Bartley et al. 1991
Big River	Big River	OT	Sommerstrom 1984
	Little NF Big River	LIT	Hassler 1988
Little NF Big River	EB Little NF Big R	LIT	Hassler 1988
Little NF Big River	Berry Gulch	LIT	Hassler 1988
	Two Log Creek	LIT	Hassler 1988
	Tramway Gulch	LIT	Hassler 1988
	NF Big River	LIT	Hassler 1988
NF Big River	EB NF Big River	LIT	Hassler 1988
NF Big River	Chamberlain Creek	LIT	Hassler 1988
Chamberlain Creek	Arvola Gulch	LIT	Hassler 1988
NF Big River	James Creek	LIT	Hassler 1988
James Creek	NF James Creek	LIT	Hassler 1988
	SF Big River	LIT	Hassler 1988
SF Big River	Ramon Creek	CC	Nielsen et al.1991
SF Big River	Daugherty Creek	LIT	Hassler 1988
Daugherty Creek	Johnson Creek	LIT	Hassler 1988
Coastal	Little River	LIT	Hassler 1988
Coastal	Buckhorn Creek	LIT	Hassler 1988
Albion River	Albion River	OT	Sommerstrom 1984
	SF Albion River	LIT	Hassler 1988
	Railroad Gulch	LIT	Hassler 1988
	NF Albion River	LIT	Hassler 1988

Table 1. continued

Drainage	Stream	Method	Source
	Marsh Creek	LIT	Hassler 1988
Big Salmon Creek	Big Salmon Creek	LIT	Hassler 1988
	Little Salmon Cr.	LIT	Hassler 1988
	Hazel Gulch	LIT	Hassler 1988
Navarro River	Navarro River	LIT	Hassler 1988
	NF Navarro River	LIT	Hassler 1988
NF Navarro River	NF Flynn Creek	LIT	Hassler 1988
NF Navarro River	SB NF Navarro R.	LIT	Hassler 1988
SB NF Navarro River	Bridge Creek	LIT	Hassler 1988
NF Navarro River	NB NF Navarro River	LIT	Hassler 1988
NB NF Navarro R.	Little NF Navarro	LIT	Hassler 1988
NB NF Navarro R.	John Smith Creek	LIT	Hassler 1988
	Mill Creek	LIT	Hassler 1988
	Indian Creek	LIT	Hassler 1988
Indian Creek	NF Indian Creek	LIT	Hassler 1988
Indian Creek	Gut Creek	LIT	Hassler 1988
	Indian Creek		
	Dick Creek	LIT	Hassler 1988
	Rancheria Creek	FR	Kimsey 1953
Rancheria Creek	Ham Canyon Creek	LIT	Hassler 1988
Rancheria Creek	Horse Creek	LIT	Hassler 1988
Rancheria Creek	Minnie Creek	LIT	Hassler 1988
Rancheria Creek	Camp Creek	LIT	Hassler 1988
Camp Creek	German Creek	LIT	Hassler 1988
Coastal	Greenwood Creek	LIT	Hassler 1988
Coastal	Mallo Pass Creek	LIT	Hassler 1988
Elk Creek	Elk Creek	LIT	Hassler 1988
	Three Springs Cr.	LIT	Hassler 1988
	Soda Fork	LIT	Hassler 1988

Table 1. continued

Drainage	Stream	Method	Source
	Sulphur Fork	LIT	Hassler 1988
Coastal	Brush Creek	OT Snider (1985)	R. Snyder,pers. comm. cited in
Coastal	Garcia River	SS	Pister 1965
Schooner Gulch	Schooner Gulch	LIT	Hassler 1988
	NF Schooner Gulch	LIT	Hassler 1988
Coastal	Fish Rock Gulch	LIT	Hassler 1988
Coastal	Gualala	SS	Pister 1965
Gualala River	NF Gualala River	OT	Sommerstrom 1984
NF Gualala River	Doty Creek	LIT	Hassler 1988
Gualala River	SF Gualala River	LIT	Hassler 1988
SF Gualala River	Franchini Creek	LIT	Hassler 1988
SF Gualala River	Sproule Creek	LIT	Hassler 1988
SF Gualala River	Marshall Creek	LIT	Hassler 1988
Gualala River	Wheatfield Fork	LIT	Hassler 1988
Wheatfield Fork	Fuller Creek	SS comm.*	P. Baker, pers.
Wheatfield Fork	Haupt Creek	SS comm.*	P. Baker, pers.
Wheatfield Fork	House Creek	LIT	Hassler 1988
Coastal	Fort Ross Creek	SS comm.*	P. Baker, pers.
Coastal	Russian Gulch	LIT	Hassler 1988
Russian Gulch	Middle Branch	LIT	Hassler 1988
Russian Gulch	East Branch	LIT	Hassler 1988
Russian River	Russian River	LIT	Hassler 1988
	Willow Creek	SS comm.	B. Cox, pers.
	Sheephouse Creek	LIT	Hassler 1988
Sheephouse Creek	unnamed trib.	LIT	Hassler 1988
	Freezeout Creek	LIT	Hassler 1988
	Austin Creek	LIT	Hassler 1988

Table 1. continued

Drainage	Stream	Method	Source
Austin Creek	Kidd Creek	LIT	Hassler 1988
Austin Creek	Ward Creek	SS	P. Baker, pers. comm.*
Austin Creek	East Austin Creek	SS	B. Cox, pers. comm.
East Austin Creek	Gilliam Creek	SS	B. Cox, pers. comm.
East Austin Creek	Gray Creek	SS	P. Baker, pers. comm.*
	Dutch Bill Creek	FR	Kimsey 1953
	Hulbert Creek	FR	Kimsey 1953
	Mark West Creek	SS	B. Cox, pers. comm.*
Dry Creek		FR	Kimsey 1952
Dry Creek	Mill Creek	FR	Kimsey 1953
Mill Creek	Wallace Creek	FR	Kimsey 1953
Dry Creek	Peña Creek	FR	Kimsey 1953
Dry Creek	Warm Springs Creek	OT	B. Cox, pers. comm.
	EF Russian River	LIT	Hassler 1988
	WF Russian River	LIT	Hassler 1988
WF Russian River	York Creek	LIT	Hassler 1988
WF Russian River	Forsythe Creek	SS	W. Jones, pers. comm.
Forsythe Creek	Mill Creek	SS	W. Jones, pers. comm.
Forsythe Creek	Seward Creek	SS	W. Jones, pers. comm.
Seward Creek	Eldridge Creek	SS	W. Jones, pers. comm.
Seward Creek	Jack Smith Creek	SS	W. Jones, pers. comm.
WF Russian River	Salt Hollow Creek	LIT	Hassler 1988
WF Russian River	Rocky Creek	LIT	Hassler 1988
WF Russian River	Mariposa Creek	LIT	Hassler 1988
WF Russian River	Fisher Creek	LIT	Hassler 1988
WF Russian River	Corral Creek	LIT	Hassler 1988

Table 1. continued

Drainage	Stream	Method	Source
Coastal	Scotty Creek	LIT	Hassler 1988
Salmon Creek	Salmon Creek	SS	B. Cox, pers.
		comm.	
	Finley Creek	SS	P. Baker, pers.
			comm.*
	Coleman Creek	SS	P. Baker, pers.
		comm.*	
	Fay Creek	SS	P. Baker, pers.
		comm.*	
	Tannery Creek	LIT	Hassler 1988
Walker Creek	Walker Creek	SS	Emig 1984
	Salmon Creek	LIT	Hassler 1988
	Arroyo Sausal Cr.	LIT	Hassler 1988
Lagunitas Creek	Lagunitas Creek	SS	Emig 1985
	Olema Creek	SS	B. Cox, pers. comm.
	Nicasio Creek	LIT	Hassler 1988
	Devil's Gulch Cr.	SS	Emig 1985
	San Geronimo Cr.	SS	Emig 1985
Bolinas Lagoon	Pine Gulch Creek	SS	B. Cox, pers.
		comm.	
Coastal	Redwood Creek	SS	B. Cox, pers.
		comm.	
San Francisco Bay tributaries	Alameda Creek	OT	John Hopkirk,pers. comm., cited in Leidy
		1984	
	San Pablo Creek	OT	letter to Paul Needham from

Table 1. continued

Drainage	Stream	Method	Source
			Willis Evans,cited in Leidy 1984
	Walnut Creek	OT	Leidy 1983
	San Anselmo Creek	OT	Fry 1936
	Corte Madera Creek	OT	Leidy 1984
	Mill Valley Creek	OT	Leidy 1984
Sacramento River	Sacramento River	OT	Fry 1973
	Feather River	OT	
			Painter et al. 1977
<u>Coastal</u>	San Gregorio Creek	SS	L. Ulmer, pers. comm.*
<u>Coastal</u>	Pescadero Creek	SS	L. Ulmer, pers. comm.*
<u>Coastal</u>	Butano Creek	LIT	Hassler 1988
<u>Coastal</u>	Gazos Creek	LIT	Hassler 1988
<u>Coastal</u>	Waddell Creek	SS	L. Ulmer, pers. comm.*
<u>Coastal</u>	Scott Creek	AT	D. Strieg, pers. comm.
Scott Creek	Big Creek	AT	D. Strieg, pers. comm.
<u>Coastal</u>	San Vicente Creek	LIT	Hassler 1988
<u>San Lorenzo River</u>	San Lorenzo River	OT	Johansen 1975
	Hare Creek	LIT	Hassler 1988

Table 1. continued

Drainage	Stream	Method	Source
Coastal	Soquel Creek	LIT	Hassler 1988
Coastal	Aptos Creek	LIT	Hassler 1988
Coastal	Carmel River	LIT	Hassler 1988
Coastal	Big Sur River	LIT	Hassler 1988

APPENDIX A

Hatcheries and Other Production Facilities that Produce Coho Salmon in California

The following information relates to hatcheries, rearing facilities, and egg taking stations that have produced or currently are producing coho salmon in California. Where historical information is given regarding the origin of the specific hatchery stock, it should be recognized that the DFG's Salmon and Steelhead Stock Management Policy prohibits the practice of importing stocks from other states or transferring stocks from other rivers within California.

DFG Facilities

Iron Gate Hatchery. During 1963-1969, adult coho returns to the Iron Gate Hatchery located on the Klamath River near Hornbrook never exceeded 500 fish. Following an intensive stocking program begun in 1966 with fish from the Cascade River in Oregon, with additional stockings in 1967 and 1969, adult coho returns to the hatchery have since been over 1,000 fish in ten spawning seasons. Returns have exceeded 2,000 fish four times, most recently in 1987; numbers typically have ranged between 400-1,500 fish.

Trinity River Hatchery. The Trinity River Hatchery located on the Trinity River near Lewiston successfully established a run of coho salmon that continued to increase in size until recently. Adult returns rarely exceeded 1,000 fish prior to 1971, but have consistently done so since then. Returns increased during the middle to late-1980s, with more than 20,000 fish in 1987, over 10,000 in 1988 and 1989, nearly 5,000 in 1990 but then decreased to less than 1,600 fish in 1991. Fish numbers then increased in 1992 and 1993 to 2,700 fish and 3,600 fish respectively. The Trinity River coho stock is also primarily of non-native origin. The first significant planting was of Eel River stock in 1964, followed by fish from the Cascade River in Oregon in 1966, 1967 and 1969. Noyo River stocks were planted in 1969 and stocks from the Alsea River in Oregon in 1970. The influence that these introductions had on Trinity River wild coho populations is unknown. About 40% of adult escapement is believed to spawn naturally in the Trinity River, mainly in the area between Lewiston Dam and Douglas City (Rogers 1973).

Mad River Hatchery. The Mad River Hatchery located on the Mad River near Blue Lake has been less successful than the Iron Gate and Trinity River hatcheries at establishing a run of coho salmon. Adult returns have fluctuated, but never have exceeded 2,000 fish and seldom (2 out of 18 years) exceeded 1,000 fish. The Mad River Hatchery stock has the most diverse heritage of any in California, with non-native stocks planted there 18 times since 1970. These plantings included stocks from 5 different Oregon streams and 3 different California streams.

Warm Springs Hatchery. The Warm Springs Hatchery located on Dry Creek, a tributary to the Russian River near Healdsburg, did not establish a persistent run of coho salmon until the mid-1980s and returns have averaged about 400 fish per year since then. The Warm Springs Hatchery stock is derived from the Iron Gate Hatchery's Cascade River stock, and from the Noyo River, Hollow Tree Creek, and Prairie Creek, which have stocks considered similar to the native run.

Noyo River Egg-taking Station. The Noyo River egg-taking station located on the South Fork Noyo River near Fort Bragg began operation in 1962 for the purpose of establishing a supply of California coho salmon eggs to enhance both depleted naturally spawning stocks and hatchery production. The number of coho trapped at the Noyo Station varied between 1,100 and 4,900 fish during 1962-1976. Numbers have fluctuated since then with over 2,600 fish in 1987, 1,000 in 1989 and less than 200 in 1992. Depending on the size of the run, a number of fish are allowed to pass over the dam to spawn naturally each spawning season. Nielsen (1991) found significant natural spawning also takes place downstream of the Noyo Station in the mainstem South Fork Noyo River and in the tributary Kaas Creek. Since 1964, the river has been routinely planted with yearling fish hatched from Noyo River eggs and raised at various hatcheries with Warm Springs and Mad River being the predominant ones. Juveniles are raised at a hatchery until yearling size, then returned to the Noyo River and held for 15 days to imprint the fish prior to their release (R. Gunter, DFG, pers. comm.).

Privately Owned and Operated Facilities

Rowdy Creek Hatchery. The Rowdy Creek Hatchery located on Rowdy Creek, a tributary to the Smith River, near Smith River, is a private hatchery and rearing facility started by the Smith River Kiwanis Club in 1972 and funded by private donations. In 1974, the members of the Kiwanis Club formed the Rowdy Creek Fish Hatchery Corporation which now owns and operates the facility. This facility emphasizes chinook salmon and steelhead production but also has produced coho salmon since the 1984-1985 brood year. Adult coho are counted at the hatchery ladder and the run has averaged about 11 fish each year since 1984. All juvenile fish raised at the hatchery are released into Rowdy Creek as yearlings (B. Will, unpubl. data and pers. comm.).

Prairie Creek Hatchery. The Prairie Creek Hatchery located on Prairie Creek near Orick began capturing returning adult coho salmon in 1972. The run generally exceeded 100 fish, increased to nearly 1,800 fish in 1988, then decreased to 186 fish in 1990. Most adults trapped at the hatchery had been previously released from the hatchery as juveniles. Since 1983, only Prairie Creek stock has been planted, but some earlier plants included stocks from Oregon, Washington and other California streams. This hatchery was closed in 1992 following termination of funding by the DFG (S. Sanders, pers. comm., cited in Brown et al., in press).

Freshwater Creek Facility. The Freshwater Creek facility located on Freshwater Creek near Eureka is operated by the Humboldt Fish Action Council (HFAC) as a salmon trapping and rearing facility. During the 1992-1993 spawning season, 5 female coho were spawned with 10 males to produce over 12,000 eggs. After initial rearing at the Yaeger Creek Hatchery, fry were transported to the HFAC's newly completed rearing site on McCready Gulch, a tributary to Freshwater Creek. These fish will be released into Freshwater Creek as yearlings (M. Hayward, unpubl. data).

Hollow Tree Creek Hatchery. The Hollow Tree Creek Hatchery and egg collection station located on Hollow Tree Creek near Leggett has been operating since 1979 and is a restoration and enhancement facility operated by the Salmon Restoration Association. The facility emphasizes fall chinook salmon production but also spawns coho salmon on site and then transports the eggs to other facilities for rearing. All coho salmon not taken for spawning purposes are released upstream. Counts of adult coho at the trap averaged about 134 fish during the 12 years that counts were taken. Numbers ranged from 52 fish in 1979, over 140 in 1980 and 1981, 14 in 1982, 184 in 1988, 15 in 1991 and 283 in 1992. Two to 5 coho salmon females were taken and spawned at the facility in 1980, 1981, 1982, 1985, 1986, 1987 and 1988. The eggs were transported either to a hatch box on Johnson Creek, a tributary to Big River in Mendocino County, Warm Springs Hatchery or the Garberville Rotary Club for rearing (K. Hans., unpubl. data).

Ten Mile River Hatchery. The Ten Mile River Hatchery, located on Georgia Pacific Corporation property on the Ten Mile River near Fort Bragg, is operated by the Salmon Restoration Association and is funded from proceeds raised from the annual Fort Bragg Salmon Barbecue. This facility began operation as a rearing facility for steelhead, which were the primary focus until the actual hatchery facility was constructed in 1990. Coho salmon were first spawned at this facility during the 1986-1987 season when two native females were used to produce about 6,000 fingerlings in the 1986-1987 season, all of which were planted into the mainstem Ten Mile River. Coho salmon were not spawned again until the 1992-1993 spawning season when they obtained their first source of native coho salmon eggs for the new hatchery. Nearly 7,000 progeny from that spawning season are still in the hatchery and will be raised to yearling size before being released into the

Appendix A. continued

Ten Mile River drainage (M. Maas, pers. comm., E. Moore, unpubl. data).

Nicasio Creek Facility. The Nicasio Creek facility located on Nicasio Creek near Nicasio was constructed in 1963 as mitigation for the construction of Nicasio Reservoir. The facility was operated by the DFG between 1963-1970 and had average adult coho returns of 422 fish each year with only 6 fish returning in 1970. The facility was closed in 1970 because of poor returns but was reopened in 1984 and operated for one year with no adult coho returning there. The facility has since been abandoned (B. Cox, DFG, pers. comm.).

San Geronimo Creek Facility. The San Geronimo Creek facility located on San Geronimo Creek near San Geronimo has been operated since 1988 by the Salmon Restoration Association. About 4-5 pairs of adult coho are captured each year by netting the fish in a ladder over an old water diversion. The adults are then spawned and their progeny reared on the stream. This facility has had water quality and temperature problems that have limited its success (B. Cox, DFG, pers. comm.).

Big Creek Hatchery. The Big Creek Hatchery is located on Big Creek Lumber Company lands on Big Creek, a tributary to Scott Creek, near Davenport. This facility was owned and operated by the DFG between 1927-1940 but was abandoned and never rebuilt after being damaged by a major flood in 1940. The facility was restored in 1982 through a local community cooperative effort and a raceway and 4 circulating pools were constructed. The hatchery is now operated by the Monterey Bay Salmon and Trout Project and DFG under a joint lease with Big Creek Lumber Company. In 1982, operations first began when Carmel River steelhead were raised at the hatchery.

Coho salmon production first began in the 1983-1984 spawning season. Spawning has been sporadic since then with the following average number of adult coho trapped/fish spawned each year since the 1984-1985 spawning season: 12 males, 9 females/6 males, 5 females. In 5 out of the 9 years of this period of record, no adult female coho salmon returned to the hatchery. An additional group of marked fish that had been produced in the hatchery during the 1989-1990 brood year, were also spawned during the 1992-1993 season: 11 males, 17 females/11 males, 17 females. The Big Creek Hatchery also rears coho salmon juveniles produced from eggs obtained from San Lorenzo River coho stocks. The average number of San Lorenzo River adult coho trapped/fish spawned each year since the 1986-1987 spawning season was 31 males, 21 females/9 males, 7 females (L. Radford, DFG, unpubl. data, D. Strieg, pers. comm.).

APPENDIX B

Coho Salmon Distribution and Occurrence Information

Information presented below regarding individual rivers and streams comes principally from DFG employees and files, Nielsen et al. (1991), Brown and Moyle (1991a), and Brown et al. (in press), which together presently represent the most definitive documentation of the coho salmon's range, distribution and occurrence in California.

South Fork Winchuck River

The South Fork Winchuck River drainage (Del Norte County) in California supports a small coho salmon population. Adult carcass counts and surveys for adult fish found 6 fish in 1991-1992 and 5 fish in 1992-1993. No fish were observed the previous three years (D. McLeod, DFG, unpubl. data).

Smith River

According to Waldvogel (1988), the Smith River drainage (Del Norte County) presently does not support a large run of coho salmon. In a 13 year survey period (1979-1980 season through the 1991-1992 season, inclusive), coho salmon counts conducted by Waldvogel (pers. comm. and unpubl. data) in a 2.74-km (1.7-mile) study reach of West Branch Mill Creek averaged about 10 adults per year. He observed only two coho in 1990 and seven in 1991 and 1992. Hallock et al. (1952) seined over 60,000 juveniles from Mill Creek in 1951, indicating that the stream once supported a substantial coho population.

Coho salmon adult carcass counts and surveys for adult fish have been conducted on a 8.45-km (5.25-mile) index study reach of Rowdy Creek since the 1985-1986 season. The number of adults counted have averaged about 8 fish per year with a high of 15 in 1988-1989 and a low of 1 fish in 1987-1988 (D. McLeod, DFG, unpubl. data). There is a private hatchery on Rowdy Creek which handles a few coho so these numbers are likely influenced by the hatchery operation.

Wilson Creek. Snorkeling and electrofishing surveys were conducted in several pools in lower Wilson Creek in June, 1987, and 5 juvenile coho were observed. Follow-up electrofishing surveys in the same general area in October, 1993, produced 9 coho juveniles (D. McLeod, DFG, unpubl. data).

Klamath River System

Mainstem Klamath River. Coho salmon historically were believed to be abundant in the lower Klamath River (Del Norte County) and Snyder (1931) reported over 11,000 coho were caught in the commercial gill-net fishery in 1919. McCormick (1958) estimated the sport catch in the lower Klamath River in 1954 was 4,000 fish. Recent data from the mainstem Klamath River indicate substantial numbers of coho salmon are present. Coho populations in the Upper Klamath Basin in California and Oregon were believed to be at least 1,600 adults prior to 1920 but are now blocked at Iron Gate Dam (Klamath River Basin Fisheries Task Force 1992). Presently, the Iron Gate and Trinity River hatcheries are considered the source of most Klamath River coho salmon and natural production is minor (Klamath Fishery Management Council 1991).

Trinity River. In the Trinity River drainage (Humboldt and Trinity counties), Hassler et al. (1988) report coho salmon spawn in the mainstem, the South Fork Trinity and in the tributaries. Coots (1957) found juvenile coho in lower Eltapom, Butter and Olsen creeks. Rogers (1973) estimated 2,098 fish spawned in the mainstem below Trinity River Hatchery during 1970, but he believed all or most of them were hatchery returns. Tuss et al. (1989) and Kisanuki et al. (1991) determined over 500 coho salmon were caught each year in 1988 and 1989 in the Native American gill-net fishery on the Hoopa Valley Reservation. Healy (1973) was able to capture downstream migrant yearling coho salmon in the mainstem, but found no juvenile coho in the South Fork Trinity. Healy (1973) believed this may have indicated at the time that the wild stock there was greatly diminished.

Coho salmon are still known to occur in the South Fork Trinity, although their numbers are low and run timing is variable. In 1985, DFG counted 127 coho entering the South Fork Trinity and nearly 40 percent of them were adipose fin-clipped, indicating most of this run was of hatchery origin (Jong and Mills, DFG, unpubl. data). In the past five years, runs have averaged 60 adults per year with a low of 1 fish in 1988-1989 and a high of 135 fish in 1991-1992 (L. Hansen, DFG, pers. comm. and unpubl. data).

Klamath River Tributaries. Brown et al. (in press) indicate coho salmon have been reported from 113 tributary streams in the Klamath River system and they believe many in the river's lower reach (Del Norte and Humboldt counties) have had their runs diminished. Small tributary streams in the middle (Humboldt and Siskiyou counties) and upper reaches (Siskiyou County) of the Klamath River still support coho salmon and many of these populations may be wild. Of the larger tributary systems, the Scott River (Siskiyou County) probably holds the largest number of wild fish. The Salmon River (Siskiyou County) probably has few coho salmon (J. West, USFS, pers. comm., cited in Brown et al., in press).

Hoppaw Creek has historically produced coho salmon with the number of juveniles rescued ranging from 60 to 1,153 (Shapovalov 1940, 1941, Murphy 1951, Kimsey 1952, 1953) but recent surveys of this stream are not available to determine coho status. Surveys in 1989 failed to find coho in Tully and Pine creeks, and no outmigrants were found in Pecwan Creek, although juveniles were found there in previous years (T. Kisanuki, USFWS, pers. comm., cited in Brown et al., in press). Turwar Creek, Hunter Creek and two of its main tributaries, High Prairie and Mynot creeks, have historically produced coho salmon based on fish rescues numbering from the low hundreds to tens of thousands from 1939 to 1952 (Shapovalov 1941, Murphy 1951, Hallock et al. 1952, Kimsey 1953). During the spring of 1989, outmigrant trapping accounted for 37 coho salmon juveniles caught during 15 trap nights in Turwar Creek and 1 coho salmon caught during 9 trap nights in Hunter Creek (T. Kisanuki, USFWS, unpubl. data). Juvenile outmigrant trapping and seining in the middle reaches of Hunter Creek conducted in May-June, 1992, captured 531 coho salmon (J. Schwabe, DFG, unpubl. data). Electrofishing surveys in West Fork Hunter Creek in October, 1993, were conducted at a stream enhancement site where large woody debris had been added and 26 coho juveniles were observed (D. McLeod, DFG, unpubl. data).

DFG has monitored juvenile salmonid populations in South Fork Ah Pah and McGarvey creeks since 1988 as part of a north coast stream survey program. August electrofishing surveys in representative sections (index reaches) of South Fork Ah Pah Creek estimated an average of 34 juveniles in the 33.4-m (110-foot) index reach in 1988-1990, 2 fish in 1992 and no fish in 1993. Similar surveys in the 42.4-m (139-foot) index reach in McGarvey Creek estimated 38 juveniles in 1988, 2 fish in 1992 and no fish in 1989 and 1993 (D. McLeod, DFG, unpubl. data). Hallock et al. (1952) seined 220 juvenile coho from McGarvey Creek in 1951.

Very few outmigrant coho salmon were trapped in 1989 by Kisanuki (unpubl. data) in Bear, Tectah and Roach creeks. Similarly low numbers of outmigrants as well as low numbers of adults were observed during 1988-1990 by Olson (unpubl. data) in Irving, Independence, Elk (including the tributaries East Fork Elk, Cougar and Mill creeks), Indian (including the tributaries East Fork Indian and Mill creeks), China, Thompson and Grider creeks.

Appendix B. continued

Redwood Creek

Coho salmon were first reported in Redwood Creek (Humboldt County) by Snyder (1908). Briggs (1949) noted that Prairie Creek, its main tributary, was used extensively for spawning by both coho and chinook salmon and that coho outnumbered chinook by about 6 to 1. Adults or juveniles have since been observed in the mainstem, its major tributary Prairie Creek, and in several tributaries of Prairie Creek (Hallock et al. 1952, Fisk et al. 1966, Burns 1971). The U.S. Bureau of Reclamation (1973) estimated that 2,000 coho spawners utilized Redwood Creek. The total coho salmon population in the Redwood Creek system still may number > 2,000 fish in some years, but most occur in the Prairie Creek drainage and probably originate from the Prairie Creek Hatchery (S. Sanders, pers. comm. and D. Anderson, pers. comm., cited in Brown et al., in press).

DFG stream surveys of a 21.6-m (71-foot) reach in Little Lost Man Creek, a tributary to Prairie Creek, indicate that coho populations have recently remained relatively stable with an average estimated 42 juveniles observed each year from 1988 to 1992. The numbers of fish using this stream are believed to have been influenced by the Prairie Creek Hatchery (D. McLeod, DFG, unpubl. data).

Little River

There is little historical data available on Little River (Humboldt County) coho salmon populations. Spawning surveys in a 3.2-km (2-mile) index reach between the Upper South Fork confluence and 0.8-km (0.5-mile) downstream of the Lower South Fork confluence have been conducted each spawning season since 1986-1987. An average of 16 adult coho were observed each year with a high of 36 fish in 1987-1988 and a low of zero fish in 1990-1991 (D. McLeod, DFG, unpubl. data).

Mad River

On the Mad River (Humboldt County), numbers of coho salmon counted over Sweasey Dam fluctuated between 2 and 725 fish during 1938-1961, 710 in 1962, and 3,580 in 1963, the last year of counting. Because counts at Mad River Hatchery fluctuated in the same range (500-1,000 fish) during 1971-1988, Brown and Moyle (1991a) believe it appears that overall coho numbers in the Mad River during this period remained relatively steady.

Lindsay Creek and its tributary Squaw Creek have produced relatively large numbers of coho salmon. Hallock et al. (1952) seined 10,663 and 6,810 juveniles from these streams in 1951. Murphy (1951) captured 11,672 juveniles in 1950 and Kimsey (1953) rescued 1,553 juveniles in 1952 from Squaw Creek. In March, 1988, 4 adult coho were observed during carcass surveys in Lindsay Creek about 400-m (0.25-mile) upstream of the mouth of Squaw Creek. In October, 1993, spot check electrofishing surveys conducted in a 38-m (125-foot) stream reach in the same area produced 23 juvenile coho salmon (D. McLeod, DFG, unpubl. data). A 28-m (92-foot) index reach of Cañon Creek was electrofished in August 1988, 1989, 1992 and 1993 (D. McLeod, DFG, unpubl. data) with 24, 4, 2 and 0 juvenile coho salmon estimated, respectively. Brown and Moyle (1991a) reported juvenile coho salmon have also been captured from Grassy, Noisy and Camp Bauer creeks. Approximately 30 m (100 feet) of lower Mill Creek was electrofished in October, 1993, and 32 coho salmon juveniles were observed (D. McLeod, DFG, unpubl. data). Spot check electrofishing surveys in Sullivan Gulch in June, 1993, produced 12 juvenile coho salmon (L. Preston, DFG, unpubl. data).

Humboldt Bay Tributaries

Streams tributary to Humboldt Bay (Humboldt County) historically have been important to the local sport fishery, but Hull et al. (1989) report estimates of coho abundance in these streams are lacking. Hallock et al. (1952) seined 8,642 juveniles from Freshwater Creek, 17,671 from Elk River and 14,243 from Jacoby Creek, indicating substantial populations in those streams. Spawning surveys conducted in North Fork Elk River on two index reaches totaling 7.4 km (4.6 miles) during the 1986-1987 season produced an actual highest count of 343 live adults, 53 carcasses and 206 redds, and total coho escapement that year was estimated at 773 fish. Spawning surveys along the same two index reaches during the 1988-1989 season produced an escapement estimate of 126 coho salmon (L. Preston, DFG, unpubl. data). Electrofishing surveys (G. Flosi, DFG, unpubl. data) conducted in conjunction with habitat mapping found small numbers of juvenile coho salmon in North Fork Elk River in 1990 (8) and 1993(6), North Branch North Fork Elk River in 1990 (5), South Fork Elk River in 1990 (20), Mc Whinny Creek in 1990 (6), Bridge Creek in 1990 (23) and Graham Gulch in 1993 (36). Recent spawning surveys (G. Flosi, DFG, unpubl. data) found evidence of coho salmon spawning in North Fork Elk River (1990-1991, 48 live adults and 3 skeletons; 1991-1992, 39 live adults and 3 carcasses; 1992-1993, 20 live adults, 12 carcasses and 18 skeletons) and South Fork Elk River (1990-1991, 20 live adults, 9 carcasses and 4 skeletons; 1991-1992, 14 live adults, 6 carcasses and 4 skeletons).

Spot check electrofishing surveys conducted in Jacoby Creek below the Quarry Road bridge in May, 1993, produced 16 juvenile coho (L. Preston, DFG, unpubl. data). The USFWS counted 24 adult coho salmon in Salmon Creek during the 1991-1992 spawning season (K. Foerster, USFWS, unpubl. data). Total coho salmon escapement in the Freshwater Creek drainage was estimated at 454 fish in 1986-1987 and 834 fish in 1987-1988 (G. Flosi, DFG, unpubl. data). Freshwater Creek has been the focus of population and habitat restoration efforts by the Humboldt Fish Action Council, which began rearing coho and chinook salmon for local population enhancement in the early 1970s. Stocking and habitat restoration efforts have also been made on other tributaries.

<u>Eel River System</u>

<u>Lower Mainstem, North Fork and Middle Fork Eel River</u>. The Eel River system (Humboldt, Trinity and Mendocino counties) probably supports the largest remaining wild populations in California. The U.S. Heritage Conservation and Recreation Service (1980) estimated the coho salmon run in the Eel River to be 40,000 fish which exceeds the more recent <u>statewide</u> coho population estimate of 33,500 fish developed by Sheehan (1991). Murphy and DeWitt (1951) believe the lower mainstem Eel River does not appear to be used by coho salmon as rearing habitat to any significant degree.

Electrofishing surveys in conjunction with habitat inventories were conducted in portions of 2 lower mainstem Eel River tributaries Jordan Creek (September 1991) and Chadd Creek (July 1992) and 4 juveniles were seen in each stream (S. Downie, DFG, unpubl. data). Recent spawning surveys found evidence of coho salmon spawning in the following lower mainstem Eel River tributary streams: Carson Creek (1987-1988, 1 live adult), Bear Creek (1987-1988, 1 live adult; 1991-1992, 2 live adults; 1992-1993, 6 live adults, 3 carcasses and 1 skeleton), and Chadd Creek (1987-1988, 1 live adult and 1 carcass; 2 skeletons in 1989-1990, and 3 skeletons in 1992-1993 (G. Flosi, DFG, unpubl. data).

Older records indicate that coho salmon were even more widespread in the Eel River drainage in the past. Coho salmon were once present in the North Fork Eel River and its tributary Bluff Creek, and the Middle Fork Eel River and its tributaries Mill, Grist, and Rock Creeks (W. Jones, DFG, pers. comm.). No outmigrants were captured by Puckett (1976) during trapping in the Middle Fork Eel River in 1959. Coho Salmon populations in the North Fork and Middle Fork Eel River systems are now believed to be extirpated (W. Jones, DFG, pers. comm.).

Upper Mainstem Eel River. According to Brown and Moyle (1991a), in the upper mainstem Eel River drainage (Mendocino County), coho salmon historically occurred as far up as Indian Creek and Tomki Creek and several of its tributary streams. Grass (1990) states during the 1946-1947 season, 47 coho salmon were recorded passing through the Van Arsdale fish facility located 253 km (157 miles) from the sea and 4.3 km (2.7 miles) upstream of the mouth of Tomki Creek but have not been recorded there since. Steiner Environmental Consultants (1990) reported the Tomki Creek drainage has been extensively studied since 1986 and no coho salmon outmigrants have been captured or adults observed.

Coho salmon presently occur in the upper mainstem Eel River drainage as far up as the Outlet Creek drainage and these stocks represent the longest run of wild coho salmon in California (W. Jones, DFG, pers. comm.). Coho salmon were recorded spawning as recently as the 1988-1989 season in the mainstem Outlet Creek (42 fish in 1987-1988, 2 fish in 1988-89) and its tributaries Long Valley (2 fish in 1987-1988, 7 fish in 1988-1989 and good numbers of juveniles in 1987 and 1990), Reeves Canyon (51 fish in 1987-1988 but zero fish in 1988-1989), Ryan (16 fish in 1987-1988, 2 fish in 1988-1989, no juveniles in 1990, 1 fish in 1992-1993), Willits (1 fish each year in 1987-1988 and 1988-1989, no fish in 1992-1993), Broaddus (24 fish in 1987-1988), Hael (5 fish in 1987-1988) and Baechtel (3 fish in 1987-1988 and 4 fish in 1988-1989) creeks (G. Flosi, DFG, unpubl. data; W Jones, DFG, unpubl. data; Brown and Moyle 1991b; L. Brown, unpubl. data). Surveys conducted during the 1989-1990 season by Nielsen et al. (1991) on 69-km (42.9-miles) of Outlet Creek and 12 of its tributaries (Baechtel, Bloody Run, Broaddus, Cherry, Davis, Hael, Long Valley, Dutch Henry, Ryan, Reeves, Upper Little Lake and Willits creeks) found no coho salmon. Jones (DFG, unpubl. data) conducted spawning surveys during the 1990-1991 and 1991-1992 seasons and found no coho salmon in Ryan and Willits creeks. His spawning surveys in 1992-1993 found one coho salmon in Ryan Creek and none in Willits, Mill and Long Valley creeks. Electroshocking surveys in October, 1993, found one juvenile coho salmon in a 30-m (98-foot) sample station in Ryan Creek (W. Jones, DFG, pers. comm.).

Van Duzen River. In the Van Duzen River (Humboldt County), coho salmon have been reported from the mainstem and a number of tributaries upstream to Grizzly Creek. Brown and Moyle (1991b) believe coho salmon populations in the Van Duzen River drainage are likely relatively small based on zero juveniles being captured during a 1967-1968 downstream migrant trapping program on the mainstem near Carlotta. These authors also report coho salmon juveniles were recently captured in small numbers from the mainstem Van Duzen River, Grizzly

Creek, and Cummings Creek. Flosi (DFG, unpubl. data) observed very small numbers of juvenile coho salmon in Stephens Creek (tributary to Grizzly Creek) and Shaw Creek in the summer of 1991. Recent spawning surveys (G. Flosi, DFG, unpubl. data) conducted in the Van Duzen River system found evidence of coho salmon spawning in the following streams: Lawrence Creek (1987-1988, 1 live adult; 1991-1992, 2 live adults; 1992-1993, 1 live adult and 1 carcass), Cummings Creek (1986-1987, 1 live adult), Hely Creek (1992-1993, 1 skeleton) and Shaw Creek (1987-1988, 3 live adults; 1991-1992, 2 live adults and 1 carcass; 1992-1993, 1 live adult and 1 carcass).

South Fork Eel River. The South Fork Eel River (Humboldt and Mendocino counties) supports the largest remaining wild stocks of coho salmon in California. Coho salmon have been counted at Benbow Dam between 1938-1975 and numbers of adults ranged from over 25,000 fish in 1947, about 14,000 fish in 1963, 4,000 fish in 1973 to 500 fish in 1975 (Murphy 1952; PFMC 1993). Early reports document thousands of juvenile coho salmon from some tributary streams to the South Fork Eel River: 4,844 fish in the Bull Creek system in 1939 (Shapovalov 1940) and 3,000 fish in 1951 (Hallock et al. 1952), 3,475 fish in Ten Mile Creek in 1951 and 4,369 fish in 1952 (Kimsey 1952, 1953), and 1,250 fish in Dean Creek in 1939 (Shapovalov 1940).

Presently, coho salmon are known to spawn mainly in the tributaries of the South Fork Eel River although limited spawning has been observed in the mainstem. Flosi (DFG, unpubl. data) observed 7 live coho adults and 75 carcasses during the 1987-1988 season and 15 carcasses during the 1988-1989 season in the mainstem South Fork Eel River. Nielsen et al. (1991) estimated 11-23 coho salmon spawned in the middle and upper reaches of the mainstem during the 1989-1990 season. Brown and Moyle (1991b) and Nielsen (pers. comm., cited in Brown and Moyle, 1991a) captured small numbers of juvenile coho salmon from the mainstem in its uppermost reaches near Branscomb during the 1989-1990 season.

Tributaries to the South Fork Eel River were extensively surveyed and sampled with both upstream and downstream migrant traps during 1983-1992 by Vaughn and Eastwood (unpubl. data), surveyed in 1987-1993 by Flosi and Downie (unpubl. data), and surveyed during the 1989-1990 season by Nielsen et al., 1991). A selection of the results of these surveys are summarized in Appendix B-1 and although the numbers are incomplete, they are representative of surveys of principal spawning areas. In the 1989-1990 spawning season, less than 300 adult coho salmon were observed in the system, which Brown et al. (in press) believe probably represents a maximum of 1,320 spawners.

Appendix B. continued

Mattole River

Brown et al. (in press) report coho salmon stocks in the Mattole River (Humboldt County) are much reduced from historic levels, numbering < 800 fish annually. Community-based restoration efforts have been underway for several years, but there is a "good" run in only one out of three years (G. Petersen, pers. comm., cited in Brown and Moyle, 1991a). Miller et al. (1990) state plantings of hatchery fish have not noticeably increased spawner returns, but they believe the program has led to the establishment of coho salmon populations in some tributary streams.

A 31.4 m (103 feet) juvenile salmonid population index reach of the South Fork Bear Creek has been electrofished since 1988. An estimated 38 juvenile coho salmon were observed in 1988, 7 in 1989, 2 in 1991 and zero in 1990, 1992 and 1993 (D. McLeod, DFG, unpubl. data).

Juvenile salmonid relative abundance surveys using electrofishing gear were conducted in July, 1993, in the upper headwater Mattole River mainstem (three locations) and 7 tributaries. A total of 16 coho juveniles were observed at two of the three mainstem survey points located approximately 3.2 km (2 miles) south of the Humboldt-Mendocino County line. There were 21 coho juveniles observed in a sub-sample of Baker Creek near the State Park boundary and coho were abundant above and below a barrier that recently washed out near the survey site. No coho were observed in Bridge, Helen Barnum, Lost Man, Thompson and Yew creeks (L. Preston, DFG, unpubl. data). Electrofishing surveys conducted at 3 pool enhancement sites in Mill Creek (T2S, R2W, S16) in September, 1993, produced 7 coho juveniles (L. Preston, DFG, unpubl. data). In September, 1993, Mill Creek (the Mill Creek downstream of the town of Petrolia) was electrofished to determine coho salmon status near completed habitat restoration work and 13 juveniles were observed at 8 locations (L. Preston, DFG, unpubl. data).

Mendocino County Streams

Mendocino County contains nearly 1,000 streams, many of which supported coho salmon at some time. Coho salmon now appear to be absent or very rare in many of the streams they historically occupied. Baker and Reynolds (1986) reported coho salmon in only 21 (30 percent) of the 70 major streams surveyed in Mendocino County. In more recent surveys (1987-1988) of 146 Mendocino County streams known to once support coho salmon, coho were found in 40 (27 percent) (W. Jones, DFG, unpubl. data). Surveys conducted by Nielsen et al. (1991) in 1989-1990 of 82 streams and tributaries (355 stream miles) in Mendocino County found low populations of coho salmon spawners in all of the streams surveyed. Only the South Fork Noyo River, which is routinely planted with large numbers of fry and smolts, had a population of coho salmon > 500 fish. Brown and Moyle (1991a) believe it is unknown how important natural reproduction is to this population or if any natural reproduction that does occur can be attributed to wild fish rather than planted fish.

Based on available information, coho salmon have not been recently observed in Duffy Gulch (tributary to South Fork Noyo River) and Whale Gulch, Jackass, Hardy, Juan, Howard, Wages, and DeHaven creeks, Arvola Gulch and James Creek (tributaries to North Fork Big River), Buckhorn Creek, Mill Creek and Indian Creek (tributaries to the Navarro River), Greenwood Creek, Mallo Pass Creek, Elk Creek, Brush Creek, Garcia River, Schooner Gulch and Fish Rock Gulch (Nielsen et al. 1991; W. Jones, DFG, pers. comm.). Of these streams, historical data only exists for Brush Creek. Murphy (1950) recorded 80 juvenile coho salmon from Brush Creek in 1948.

Fish rescue records from Usal Creek indicate 3,963 juveniles were collected in 1940 (Shapovalov 1940), 60,510 in 1944 (Shapovalov 1945), 61,133 in 1945 (Shapovalov 1949), 11,455 in 1951 (Kimsey 1952), and 13,864 in 1952 (Kimsey 1953). Considering that only fish considered in danger were collected during these rescue operations, Brown and Moyle (1991a) believe Usal Creek once supported a substantial juvenile coho salmon population. Coho salmon had not recently been observed in the Usal Creek drainage until last summer when coho juveniles were seen during electrofishing surveys in South Fork Usal Creek by Georgia Pacific biologists (W. Jones, DFG, pers. comm.).

Information regarding a selected number of representative Mendocino County streams is presented below and is cited from Nielsen et al. (1991) unless otherwise noted. Nielsen et al. (1991) indicate that the methods they used in their study tend to underestimate the actual number of spawners. They also state that their numbers seem low even if off by several orders of magnitude.

Ten Mile River. Estimates based on carcass and skeleton counts in the winter of 1989-1990 indicated a range of 31-55 coho salmon spawners in Ten Mile River. Most of the carcasses, skeletons and redds were observed in the lower Middle Fork and lower South Fork of Ten Mile River. Redds were noted in Bear Haven Creek; an unspecified number of live coho, 18 redds and 2 skeletons were observed in Redwood Creek and the upper South Fork Ten Mile River, and 3 live coho, 2 redds and 1 skeleton were observed in Churchman Creek. Extensive barrier removal took place in Ten Mile River in the 1970s-1980s. Coho enhancement in the river included the planting of 6,000 coho juveniles in June 1987. The U.S. Bureau of Reclamation (1973) estimated the run size as 6,000 coho spawners in 1973. Even if it is assumed the 1973 estimate is high by a factor of 10, Brown and Moyle (1991a) believe the present population is well below this level.

Pudding Creek. Counts of live fish indicated 38-50 coho spawners using Pudding Creek in 1990. Redds were found throughout the creek at a density of about 1.57 per 1.6-km (1-mile). Surveys of juveniles in the summer of 1990 indicated that the entire stream was being used as rearing habitat even though the density of juveniles was relatively low compared to other Mendocino County streams (W. Jones, DFG, unpubl. data). Little Valley Creek, a tributary that once supported coho salmon, apparently no longer supports a spawning population (W. Jones, DFG, pers. comm.).

Earlier data indicate a more substantial population of coho salmon in Pudding Creek. In the winter of 1957-1958, Allan (1958) counted 1,357 naturally produced coho salmon at the Pudding Creek egg collecting station (no longer operating). The population estimated in 1990 was roughly 1/20th of the 1957-1958 run. Even allowing for a substantial underestimate in 1990, Brown and Moyle (1991a) believe it appears that the run in Pudding Creek has declined.

South Fork Noyo River. In the winter of 1989-1990, a total of 319 adult coho and 91 grilse were passed over the weir located at the DFG egg taking station on the South Fork Noyo River. Based on carcass counts below the weir in conjunction with fish counts at the weir, the estimated total spawning population in the South Fork Noyo River was 3,511 coho salmon in 1990. Kass Creek and the South Fork Noyo River below the weir contributed 80 percent of the carcasses indicating that a substantial amount of natural reproduction was occurring. Carcasses were recovered in both Parlin Creek and North Fork of South Fork Noyo River, indicating natural reproduction above the weir as well. Brown and Moyle (1991a) indicate it is not known how many of these fish were the result of plantings or natural reproduction.

The Bureau of Reclamation (1973) estimated a population size of 6,000 fish in 1973 for the entire Noyo River drainage. Without counts from the North Fork Noyo River, Brown and Moyle (1991a) believe it is impossible to determine if the 1990 population estimate of over 3,500 fish is comparable. Given the 1990 estimate in the hatchery supplemented South Fork Noyo River, they believe the

1973 estimate is probably high for the entire system but by less than a factor of two.

Little North Fork Noyo River. During the late 1960s, Burns (1971, 1972) evaluated logging impacts on salmonid habitat and populations in northern California coastal streams, including the Little North Fork Noyo River. In assessing the impacts of logging to fishery resources, Burns evaluated juvenile salmonid abundance among other parameters in each stream for three summers: one before, one during, and one after logging. Burns (1972) reported a total juvenile population estimate for his four approximate 100 m (328 feet) study reaches of 698 coho juveniles before logging to 255 coho juveniles after logging, whereas juvenile steelhead trout numbers changed from 19 to 29 over the same period.

Valentine and Jameson (1993) repeated aspects of Burns' work on the Little North Fork Noyo River in 1992 near the same vicinity as Burns' study reaches. Juvenile salmonid population estimates within their four 100-m (328-foot) study reaches ranged from 3-102 for coho salmon and from 29-91 for steelhead trout. While the total salmonid biomass was similar across the two studies and during the 1966-1969 and the 1992 time period, the species composition since 1969 has inverted from primarily coho salmon to primarily steelhead trout. While other factors may also be involved, Valentine and Jameson (1993) suggest that the decline in the stream channel's average depth in response to past logging practices seems the most likely instream parameter causing the inversion in salmonid species composition in Little North Fork Noyo River.

Caspar Creek. Surveys in the winter of 1989-1990 indicated a spawning population of 30-35 coho salmon based on skeleton counts. Redds were most abundant in the mainstem but successful spawning also occurred above weirs on both the North and South Fork Caspar Creek. Juvenile coho salmon were observed in both the North and South Fork Caspar Creek (R. Nakamoto, unpubl. data). No evidence of coho salmon spawning was observed in Caspar Creek in 1990-1991 and 37 adults and 2 adults were counted in 1991-1992 and 1992-1993, respectively (W. Jones, DFG, unpubl. data). Surveys conducted in the fall of 1993 in South Fork Caspar Creek found 15 coho salmon juveniles in only 1 out of 8 sampling stations (B. Valentine, CDF, unpubl. data).

Historical data for Caspar Creek consists of juvenile population estimates and outmigrant trapping. Graves and Burns (1970) trapped 613 juvenile coho salmon from South Fork Caspar Creek and 1,770 in 1968. Burns (1971) estimated juvenile populations in a 2.4 km (1.5 mile) reach of North Fork Caspar Creek in 1967

(122-313 fish), 1968 (194-359 fish), and 1969 (1,105-2,724 fish). More recently, Jones (DFG, unpubl. data) captured 1,697 yearlings and 34,955 young-of-year coho salmon during outmigrant trapping on Caspar Creek in April and May, 1989. Jones' (DFG, unpubl. data) trapping results during the same time frame in subsequent years were as follows: 1990 (2,020 yearlings and 3,932 young-of-year), 1991 (787 yearlings and 3,632 young-of-year), 1992 (615 yearlings and 4,311 young-of-year), and 1993 (1,287 yearlings and 8,027 young-of-year). The size of the adult population producing these juveniles is not known.

South Fork Big River. Winter surveys in 1989-1990 found no coho salmon carcasses or skeletons in the South Fork Big River and tributary streams Kelley Gulch and Ramon, Mettick, Anderson, Daugherty, Soda, and Gates creeks. There were 4 live fish, tentatively identified as coho salmon, observed in Ramon Creek. Redds were identified in Ramon Creek (13), Daugherty Creek (6), and the mainstem South Fork Big River (58), although the species digging the redds could not be identified. The estimated number of spawning coho salmon in the South Fork Big River was 17-23 fish in 1990. Johnson Creek, a tributary not included in the winter surveys, had a coho enhancement project running from 1981-1987. This included a plant of 2,500 fry in 1987 which could account for some or all of the spawning activity observed in 1990. Spawning by wild fish or progeny of previously planted fish may also have occurred.

The estimated coho salmon spawning run for the Big River drainage was placed at 6,000 fish in 1973 (U.S. Bureau of Reclamation 1973. According to Brown and Moyle (1991a), the present population appears to be well below this earlier estimate even allowing for estimation errors on the order of 10 times in both years. Recent surveys of most of the other Big River tributaries historically supporting coho salmon indicate that coho are still present though the size of the runs are not known (W. Jones, DFG, pers. comm.). Electrofishing surveys (G. Flosi, DFG, unpubl. data) conducted in conjunction with habitat mapping found juvenile coho salmon in the following South Fork Big River tributaries: Gates Creek in 1988 (17), Soda Creek in 1988 (13) and 1993 (6), and Johnson Creek (2).

Little River. Winter surveys in 1990 identified 2 live coho salmon and 9 redds in the lower mainstem Little River. Jones (DFG, unpubl. data) observed no coho salmon adults and 1 redd in Little River in 1990-1991, 43 adults and 35 redds in 1991-1992 and 1 adult coho salmon in 1992-1993. Outmigrant trapping data developed by Jones (DFG, unpubl. data) indicated more coho salmon spawning in Little River than was indicated by the carcass surveys. His trapping results in March-June of each year were as follows: 1988 (1,111 yearlings and 565 young-of-year), 1989 (2,123 yearlings and 503 young-of-year), 1990 (1,347 yearlings and 1,085 young-of-year), 1991 (327 yearlings and 203 young-of-year), 1992 (1 yearling and 489 young-of-year) and 1993 (689 yearlings and 851 young-of-year).

South Fork Garcia River. Winter surveys in 1989-1990 found no coho salmon in the lower two miles of the South Fork Garcia River though Pister (1965) collected them in his study. Brown and Moyle (1991a) state the Garcia River system received a stocking of smolts in the late 1980s. There is a small remnant run persisting somewhere in the Garcia River though the number and location of spawners is unknown (W. Jones, DFG, pers. comm.).

Sonoma County Streams

In Sonoma County, coho salmon are present in Salmon Creek, Russian River, Gualala River, and their tributaries. Brown and Moyle (1991a) indicate coho salmon have also been reported from Fort Ross Creek and Russian Gulch but these streams have not been recently surveyed.

Salmon Creek. The Salmon Creek population is small at present and its survival appears to be tenuous (B. Cox, DFG, pers. comm.). The tributary Coleman Valley Creek no longer supports coho salmon (W. Jones, DFG, pers. comm.). The whole Salmon Creek drainage was heavily damaged by a large storm in 1982 that affected riparian vegetation.

Gualala River. The Gualala River likely supports a small coho salmon population (B. Cox, DFG, pers. comm.). Pister (1965) captured coho while electrofishing the river in 1965. Any wild fish that are present most likely use the North Fork which is small but well forested; however, recent surveys of the North Fork Gualala failed to find any coho. Recent plants of hatchery fish were made in the Little North Fork in an effort to reestablish a population but were unsuccessful, presumably due to problems with BKD (W. Jones, DFG, pers. comm.). The U.S. Bureau of Reclamation (1973) estimated the coho salmon spawning population in the Gualala River system to be 4,000 fish in 1973.

Russian River. Brown and Moyle (1991a) report coho salmon from the Russian River and 27 tributary streams, most of which no longer maintain populations. Willow Creek, the lowermost tributary, still maintains a run of 50-75 fish per year (B. Cox, DFG, pers. comm.). Austin Creek had a run in the past but none have been observed in the past 10 years. Several streams, including Green Valley Creek and Redwood Log Creek (a tributary to Peña Creek), have good habitat or are rumored to contain coho salmon but have not been sampled in recent years. Dry Creek and Warm Springs Creek had wild populations before the construction of Sonoma Reservoir but these populations may now be gone below the dam (B. Cox, DFG, pers. comm.). Warm Springs Hatchery is located below Warm Springs Dam and accounts for yearly plants of coho salmon into the system. Adult returns to the hatchery have been relatively stable since the mid-1980s and have averaged about 400 coho salmon per year. All production in the East Fork Russian River was lost with the construction of Mendocino Reservoir.

Recent surveys of Peña Creek and all West Fork Russian River tributaries prior to 1993 indicated that none of them support coho salmon populations anymore (W. Jones, DFG, pers. comm.). Two live adult coho were observed in Mark West Creek but were likely strays from Warm Springs hatchery. Surveys conducted in November, 1993, found 4 coho salmon juveniles in Redwood Creek (tributary to Maacama Creek) and 43 juvenile coho in Green Valley Creek (M. Faucet, pers. comm.).

<u>Marin County Streams</u>

Several coastal streams in Marin County still maintain small runs of coho salmon (B. Cox, DFG, pers. comm.), but there are insufficient historical data to determine trends. Redwood Creek has a run of about 75 or more fish (B. Cox, DFG, pers. comm.). Pine Gulch Creek, the main tributary to Bolinas Lagoon, has been reported to support coho salmon in the past but there is no data on the present status of this population. Walker Creek, a tributary to Tomales Bay, had a run of coho salmon in the past but the run is now restricted to occasional sightings of fish (B. Cox, DFG, pers. comm.). Brown and Moyle (1991a) report the stream was planted in 1979 and 1980 but both attempts to increase the population have apparently failed.

<u>Lagunitas creek</u>. Smith (1986) believes the present coho salmon population in Lagunitas Creek has been significantly reduced from historical levels due primarily to construction of Kent and Nicasio Reservoirs. Quinn and Allen (1969) believe this decline occurred despite efforts to preserve and enhance the run in the early to mid-1960s after construction of Nicasio Reservoir. Annual surveys (1-2 days each) of coho salmon in portions of the Lagunitas-San Geronimo Creek system since 1984-1985 have varied, but indicate the spawning run is generally < 100 fish (B. Cox,

DFG, pers. comm.). This is in spite of stocking of coho juveniles (Noyo River stock) in 1985 (20,040 fish), 1987 (3,888 fish), and 1988 (5,000 fish) (B. Cox, DFG, pers. comm.). Redd counts conducted during the 1990-1991 season indicated only 20 pairs of coho salmon spawning in Lagunitas Creek during very low flows that greatly restricted upstream passage of fish (L. Cronin, pers. comm., cited in Brown and Moyle 1991a). Stream surveys indicate that about 400-500 adult coho salmon were present in the Lagunitas Creek system (including Devil's Gulch and Olema and San Geronimo creeks) during the 1991-1992 spawning season, which is the highest number seen in the last 7-8 years (B. Cox, DFG, pers. comm.). Approximately 94-116 coho salmon adults and 41-53 redds were observed during an extensive survey of Lagunitas and San Geronimo creeks in January 1992 (W. Lifton, Entrix, Inc., unpubl. data). An enhancement hatchery (using local spawners) recently has operated on San Geronimo Creek (B. Cox, DFG, pers. comm.).

San Francisco Bay Tributaries

Within San Francisco Bay, coho salmon runs have been extirpated, or nearly so, but prior to extensive urbanization around the bay, most streams with suitable habitat were believed to have had coho salmon. Leidy (1983) noted spawning migrations occurred in Walnut Creek during the 1950s to mid-1960s. Coho salmon have been recorded from Corte Madera (San Anselmo) Creek (Fry 1936, Hallock and Fry 1967) and Mill Valley Creek (Hallock and Fry 1967), and juvenile coho salmon were captured in both streams during Leidy's (1984) extensive surveys of San Francisco Bay streams. There have been no coho salmon observed in Corte Madera Creek in the last 8-9 years (B. Cox, DFG, pers. comm.).

Sacramento River System

It is likely that the Sacramento River system once supported coho salmon populations given the great distances coho are known to travel up other large rivers (e.g. Columbia and Klamath rivers) and based on older records (Jordan and Jouy 1881, Jordan and Gilbert 1881, Eigenmann 1890). The size of the coho salmon run in the Sacramento River system in the late 1800s and early 1900s is unknown but report wild stocks were likely extirpated before any good records were kept. Hallock and Fry (1967) report the DFG attempted to re-establish coho salmon in the Sacramento River system in 1956-1958 when yearlings from the Lewis River in Washington were released into Mill Creek (Tehama County). The returning adults scattered throughout the drainage, with the largest concentrations occurring in Battle Creek, where they had been raised (Coleman Hatchery), and Mill Creek, where they were planted. Since then, small numbers of coho salmon have been consistently identified at Nimbus Hatchery (Jochimsen 1971, 1973a,b 1974, 1976, 1978a,b,c), and they also have been taken in the Feather River (Schlichting 1974, Painter et al. 1977).

Streams South of San Francisco Bay

Most natural production of coho salmon in the smaller streams south of San Francisco Bay appears to have been lost due to the 1976-1977 drought which exacerbated existing poor habitat conditions (D. Streig, pers. comm., cited in Brown et al. in press). Hope (1993) indicates coho salmon have been reported as far south as Monterey County in the Salinas River, Big Sur River and Carmel River; however, formal documentation of numbers is not available (J. Nelson, DFG, pers. comm.). These streams presently do not have runs of coho salmon (J. Nelson, DFG, pers. comm.). Brown and Moyle (1991a) and Hope (1993)indicate that in San Mateo County, streams supporting coho in the 1970's were Pescadero, Gazos, Butano and San Gregorio creeks but these stocks appear to have been extirpated as of 1986. According to Hope (1993), in Santa Cruz County, coho were extirpated from Pescadero (tributary to the Pajarro River), Corralitos, and Soquel creeks by 1968, Aptos Creek by 1973, and San Vicente Creek by 1982. These extirpations of coho stocks leave Scott and Waddell creeks and the San Lorenzo River as the only streams south of San Francisco Bay which still support coho salmon populations.

Waddell and Scott Creeks. According to Brown et al. (in press), the coho salmon runs in Waddell and Scott creeks are the most southern natural coho populations on the North American Pacific coast, the closest population being 160km (nearly 100 miles) northward in Marin County's Redwood Creek. Fish in these two streams have a rigid 3-year life cycle and late run and spawning times (Shapovalov and Taft 1954; J. Smith, pers. comm., cited in Brown et al. in press). Thus, Brown et al. (in press) believe these fish apparently show unique adaptations to this southernmost region of the species' range and likely constitute a distinctive segment of the gene pool of the species despite the introgression of genes from imported stocks.

Waddell Creek presently maintains a much-reduced natural coho salmon run. Hope (1993) and Brown et al. (in press) report the stream was heavily planted with imported juvenile coho salmon in 1913, 1915, 1929, 1930, 1933, 1966 and the early 1970s. A number of imported stocks have been introduced by private aquaculturists in recent years, but records of egg sources were not kept (D. Strieg, pers. comm., cited in Bartley et al. 1991). Between 1930-1940, the coho salmon population varied between 120-633 spawners (Shapovalov and Taft 1954). The present run is about 50 fish in better years, but much less in poor years (J. Smith, pers. comm., cited in Brown et al. in press). Runs considered to be "good" occur every third year, with the most recent in 1989-1990. Lack of early rainfall in the 1990-1991 spawning season prevented adults from migrating upstream during most of their normal time-frame, and reproduction was very low (J. Smith, pers. comm., cited in Brown et al. in press). Smith (1992a,b) estimated there were approximately 65 adults for the 1991-1992 run in Waddell Creek, but at least 3 probable coho redds were destroyed by scouring following a post-spawning storm. There were no coho salmon observed in Waddell Creek during spawning surveys and carcass counts conducted during the 1992-1993 season (J. Nelson, DFG, pers. comm.).

Scott Creek also maintains a natural coho salmon run which is much-reduced in size from earlier population estimates. Hope (1993) reports the stream was heavily planted with imported juvenile coho salmon in 1913, 1915, 1929, 1930, 1932-1939, and 1967-1968. Shapovalov and Taft (1954) estimated the average annual coho salmon population was 522 adults in 1936-1939 and 350 adults in 1930-1940. Hope (1993) estimated the average annual coho population in Scott Creek to be 20-30 fish in 1980-1990. Brown et al. (in press) estimate the present coho population in Scott Creek to be 30-40 fish, although this run is likely to have been mixed with stray fish from nearby Waddell Creek, which they believe is a natural occurrence. There is believed to be a higher coho salmon stray rate from Scott Creek into Waddell Creek because the sandbar separating Waddell Creek's lagoon from the ocean breaches sooner than Scott Creek's lagoon (J. Nelson, DFG, pers. comm.). Snorkeling surveys in conjunction with carcass counts conducted during the 1992-1993 spawning season on Scott Creek (D. Streig, pers. comm.) counted 28 adult coho salmon. Carcass surveys conducted on Scott Creek by the DFG counted 2 live coho and 8 carcasses (J. Nelson, DFG, pers. comm.). Scott Creek and its tributary, Big Creek, have been under intensive rehabilitation efforts and may provide the best habitat for coho salmon south of San Francisco Bay (D. Streig and J. Smith, pers. comm., cited in Brown et al. in press). There presently is an enhancement hatchery on Big Creek that uses local spawners.

San Lorenzo River. Hope (1993) indicates that the coho salmon population in the San Lorenzo River during the time period 1930-1940 was estimated at 1,500-2,000 fish. The San Lorenzo River lost its coho salmon population after the 1976-1977 drought; however, much or all of that population was the result of stocking from the 1950s through the mid-1970s (J. Smith, pers. comm., cited in Brown et al. in press). Brown and Moyle (1991a) and Hope (1993) report planting of smolts from Noyo River, Prairie Creek, and Scott Creek stocks have reestablished coho returns to the system, and fish returning to the river have been trapped and spawned by the Monterey Bay Salmon and Trout Project in an effort to establish a resident stock. Hope (1993) estimated the average annual coho salmon population size in the San Lorenzo River for the following time periods: 5 year average for 1980-1985 (10-20 fish), 5 year average for 1985-1990 (100-200 fish), 1990-1991 (50 fish), and 1991-1992 (40-50 fish). The number of adult fish trapped in this stream reached an all time low in 1989 and Brown et al. (in press) believe it is unknown if there is adequate suitable habitat for a self-sustaining population to be established.

Appendix B-1.

Coho Salmon Distribution and Occurrence Information for the South Fork Eel River

Abundance information on adult coho salmon in the mainstem and tributary streams of the South Fork Eel River known to have contained spawning populations in the past. Tributaries for which no information is available are not included, although most are small and probably contained few fish. Data presented here comes from Brown and Moyle (1991a) and has been expanded to include additional information recently made available to the DFG.

Stream	Time Period	Abundance Information	Source
Mainstem	Jan. 1988	75 carcasses, 7 live coho	A
	Dec. 1988-Jan.1989	15 carcasses, 2 skeletons	A
Bull Creek	Dec. 1987-Jan.1988	2 carcasses	A
	Dec.1988, Jan.1990	None observed	A
Squaw Creek	Dec. 1987-Jan. 1988	1 live coho observed	A
	Dec. 1988-Jan. 1989	None observed	A
	Jan. 1990		
Sproul Creek and tributaries	Dec. 1992	3 live coho, 1 skeleton	A
Canoe Creek	Jan. 1988	None observed	A
Elk Creek	Dec. 1987, Dec. 1988, Jan.-Feb. 1990	None observed	A
Anderson Creek	Jan. 1988	1 carcass	A
	Dec. 1988-Jan. 1989	None observed	A
	Jan. 1990		
Redwood Creek and tributaries	1989-1990	6 carcasses in 11 surveys; estimated 10-12 spawners	B
(Branscomb)	Jan. 1993	6 live coho, 1 carcass	A
East Branch South Fork	1980-1990	Low numbers	C,D
Low Gap Creek	Dec. 1988-Jan. 1989	None Seen	A

	Jan. 1990		
	1989-1990 season	None seen in 5 surveys	B
Indian Creek	Jan. 1988	10 carcasses and 3 live coho 4 skeletons	A
	Dec. 1988-Jan. 1989	1 carcass	A
	Jan. 1990	None observed	A
	1989-1990 season	No coho in 11 surveys	B
Standley Creek	Jan. 1988, Jan. 1990	None observed	A
Piercy Creek	1989-1990 season	Not previously recorded here; 1 carcass found in 9 surveys	B
McCoy Creek	Jan. 1988	None observed	A
	1989-1990 season	None observed in 5 surveys	B
Bear Pen Creek	Feb. 1988, Jan. 1990	None observed	A
Red Mountain Creek	Jan. 1988	None observed	A
	Jan.-Feb. 1990	None seen in 8 surveys	B
Wildcat Creek	Jan. 1988, Jan. 1990	None observed	A
Hollow Tree Creek mainstem	Dec. 1987	16 carcasses, 3 live coho	A
	Dec. 1988-Jan. 1989	11 carcasses, 14 live coho 8 skeletons	A
	Jan. 1990-Feb. 1991	3 coho (unspecified)	F
	Jan. 1991-Feb. 1992	49 coho (unspecified)	F
	Jan. 1992-Feb. 1993	5 live coho, 6 skeletons	A
	Jan. 1992-Feb. 1993	32 skeletons	F
Redwood Creek	Dec. 1987-Jan. 1988	5 carcasses, 20 live coho	A
	Dec. 1988	1 carcass, 1 live coho	A
	Dec. 1992-Jan. 1993	13 live coho	A
Butler	Jan. 1992	1 live coho	A
Huckelberry	Jan. 1993	2 live coho	A
Michaels	Dec. 1992	3 live coho	A

Appendix B-1

20 mi of mainstem and tributaries	Jan.-Feb. 1990	Estimated 11-17 coho spawners based on carcasses. Estimated 146-158 combined coho and chinooks based on live fish counts	B
Hollow Tree Creek	1979-1992 seasons, inclusive	Counts at egg-taking station: 53, 145, 142, 14, 0, 49, 314, 153, 89, 184, 162, 15, 0,283	E,G,B
Walters Creek	1985-1990	None seen in recent surveys	
Cedar Creek	1989-1990 season	Estimated 11-23 from carcass counts; estimated 20-33 from live fish counts	B
Rattlesnake Creek and tributaries	Dec. 1987	3 carcasses and 1 live coho	A
	Dec. 1988-Jan. 1989	None observed	
	1989-1990 season	None observed in 7 surveys	B
Ten Mile Creek and tributaries	Dec. 1987	1 live coho, 3 carcasses	A
	1989-1990 season	None in 6 surveys	B
Redwood Creek (Redway)	Jan. 1988	70 carcasses, 1 skeleton	A
	Dec. 1988	2 carcasses, 1 live coho	A
Redwood Creek (Redway)	1983-1992 season, inclusive	Counts at trap operated by PCFFA: 3, 15, 2, 51, 16, 12, 13, 1, 25, 32	H
Streeter Creek	Jan. 1988	1 carcass	A
	Dec. 1988-Jan. 1989	None observed	A
Jack of Hearts Creek	Jan. 1988	2 carcasses, 2 skeletons	A
	1989-1990 season	3 carcasses; estimated 29-39 combined coho and chinook, based on 11 surveys	B
Deer Creek	1990	None observed	B
Little Charlie	Late 1989	None observed	B

Appendix B-1

Creek			
Dutch Charlie Creek	Jan. 1988	6 carcasses	A
	1989-1990 season	None in 8 surveys	B

Information sources.

A= G. Flosi, DFG, unpubl. data; B= Nielsen et al. (1991); C= Puckett (1976), D= S. Downie, DFG, unpubl. data; E= Sanders (1982a,b,c, 1983); F= W. Jones, DFG, pers. comm. and unpubl. data; G= K. Hans, unpubl. data; H= H. Vaughn, unpubl. data

APPENDIX C

Coho Salmon Life History Information

The following information relates to the life history of coho salmon.

Description: Coho are fairly large salmon, with spawning adults typically attaining 55-70 cm Fforklength (FL) and weighing 3-6 kg. They have 9-12 dorsal fin rays, 12-17 anal fin rays, 13-16 pectoral fin rays, and 9-11 pelvic fin rays. Lateral line scales number 121-148 and the scales are pored. There are 11-15 branchiostegal rays on either side of the jaw. Gill rakers are rough and widely spaced, with 12-16 on the lower half of the first arch.

Spawning adults are generally dark and drab. The head and back are dark green, the sides are a dull maroon to brown, and the belly is grey to black. Females are paler than males. Spawning males are characterized by a bright red lateral stripe, hooked jaw, and slightly humped back. Both sexes have small black spots on the back, dorsal fin, and upper lobe of the caudal fin. The adipose fin is finely speckled, imparting to it a grey color; except for the caudal, the other fins lack spots and are tinted orange. The gums of the lower jaw are grey, except the upper area at the base of the teeth, which is generally whitish (Fry 1973). Parr have 8-12 narrow parr marks centered along the lateral line. The marks are narrow and widely spaced.

Taxonomic relationships: Coho salmon are one of five species of Pacific salmon (*Oncorhynchus*) found in California. They do not appear to have the genetically distinct, temporally segregated runs that characterize the more abundant chinook salmon and steelhead trout. However, given the homing capabilities of coho salmon, it is reasonable to expect that at least some coastal areas have their coho adapted for local environmental conditions with regard to run-timing and other life-history characteristics. A recent study of allozyme variation in California coho salmon by Bartley et al. (1992) showed that most variant alleles occurred at three or fewer localities, although the distribution of those alleles did not follow any particular pattern. These authors concluded that gene flow among California populations was high from an evolutionary perspective, but low in terms of the actual number of individuals (1.4 per generation) being exchanged between populations. Further population genetic studies using mitochondrial DNA are needed. Overall, coho populations in California are the southernmost for the species and presumably have adapted to the extreme conditions (for coho salmon) of many coastal streams. Bartley et al. (1992) believe there is some indication from allozyme data that California stocks may be somewhat genetically differentiated from stocks in more northern areas.

History: The life history of the coho salmon in California has been well documented by Shapovalov and Taft (1954) and Hassler (1987). Coho salmon generally return to their natal streams to spawn after spending two years in the ocean except some males called "jacks" may return after one growing season in the ocean. The spawning migrations begin after heavy late-fall or winter rains breach the sand bars at the mouths of coastal streams, allowing the fish to move into them. However, migration typically occurs when stream flows are either rising or falling, not necessarily when streams are in full flood. The timing of their return varies considerably, but in general they return earlier in the season in more northern areas and in the larger river systems (Baker and Reynolds 1986). In the Klamath River, the coho run between September and late-December, peaking in October-November. Spawning itself occurs mainly in November and December (USFWS 1979). The early part of the run is dominated by males, with females returning in greater numbers during the latter part of the run. Baker and Reynolds (1986) found the coho run in the Eel River occurs 4-6 weeks later than that in the Klamath River; arrival in the upper reaches of the Eel River peaks in November-December.

In the short, coastal streams of California, most coho return during mid-November through mid-January (Baker and Reynolds 1986). For example, in Waddell Creek, spawning migrations often do not occur until November or December (Shapovalov and Taft 1954). In Oregon streams, Sandercock (1991) found spawning can occur as late as March if drought conditions delay rains or runoff. Coho salmon migrate up and spawn mainly in streams that flow directly into the ocean or in tributaries of large rivers. Generally, coho spawn in smaller streams than used by chinooks.

Females choose the spawning sites (redds) usually near the head of a riffle, just below a pool, where the water changes from a laminar to a turbulent flow and there is a medium to small gravel substrate. The flow characteristics of the location of the redd usually ensure good aeration of eggs and embryos, and flushing of waste products. The water circulation in these areas facilitates fry emergence from the gravel. Each female builds a series of redds, moving upstream as she does so, and deposits a few hundred eggs in each. Thus, spawning may take about a week to complete and a female can lay between 1,400-7,000 eggs. There is a positive correlation between fecundity and size of females. Hassler (1987) noted a dominant male accompanies a female during spawning, but one or more subordinate males also may engage in spawning. He also found both males and females die after spawning, although the female may guard a nest for up to two weeks.

Appendix C

Embryos hatch after 8-12 weeks of incubation, the time being inversely related to water temperature. Hatchlings remain in the gravel until their yolk sacs have been absorbed, 4-10 weeks after hatching. According to Baker and Reynolds (1986), under optimum conditions, mortality during this period can be as low as 10 percent; under adverse conditions of high scouring flows or heavy siltation, mortality may be close to 100 percent. Upon emerging, they seek out shallow water, usually along the stream margins. Initially they form schools, but as they grow bigger the schools break up and the juveniles (parr) set up individual territories. Chapman and Bjornn (1969) determined the larger parr tend to occupy the heads of pools; the smaller parr are found further down the pools. As the fish continue to grow, they move into deeper water and expand their territories until, by July and August, they are in deep pools. Optimal habitat seems to be in deep pools created by large, woody debris and boulders in heavily shaded sections of stream.

As water temperatures decrease into the fall and winter months, fish stop or reduce feeding due to lack of food or in response to the colder water and growth rates slow down. During December-February, winter rains result in increased stream flows and by March, following peak flows, fish again feed heavily on insects and crustaceans and grow rapidly. Toward the end of March and the beginning of April they begin to migrate downstream and into the ocean. Outmigration in California streams typically peaks in mid-April to mid-May, if conditions are favorable. Migratory behavior is related to rising or falling water levels, size of fish, day length, water temperature, food densities, and dissolved oxygen levels. At this point, the outmigrants are about one year old and 10-13 cm in length. The fish migrate in small schools of about 10-50 individuals. Parr marks are still prominent in the early migrants, but the later migrants are silvery, having transformed into smolts.

After entering the ocean, the immature salmon initially remain in inshore waters close to their parent stream. They gradually move northward, staying over the continental shelf. Coho salmon can range widely in the north Pacific, but the movements of California fish are poorly known. Most coho caught off California in ocean fisheries were reared in the Columbia River or in coastal Oregon streams either naturally or in hatcheries. In 1990, for instance, 112,600 coho were caught in commercial and recreational ocean fisheries, which greatly exceeds the present production capability of California populations alone (A. Baracco, pers. comm.). Oceanic coho tend to school together. Although it is not known if the schools are mixed, consisting of fish from a number of different streams, fish from different regions are found in the same general areas. Adult coho salmon are primarily piscivores, but shrimp, crabs, and other pelagic invertebrates can be important food in some areas.

Coho salmon move upstream in response to an increase in stream flows caused by fall storms, especially in small streams when water temperatures are 4-14° C or slightly higher. Spawning sites are typically at the heads of riffles or tails of pools where there are beds of loose, silt-free, small to medium sized gravel and cover nearby for the adults. Unlike other salmon species, coho salmon redds were found by Emmett et al. (1991) to be situated in substrates composed of up to 10 percent fines, but spawning success and fry survival generally are favored by very clean gravel with < 5 percent fines (CDFG 1991). Hassler (1987) determined spawning depths are 10-54 cm, with water velocities of 0.2-0.8 m/sec. Emmett et al. (1991) determined optimal temperatures for development of the embryos in the gravel is 4.4-13.3° C, although eggs and alevins can be found in 4.4-21.0° C water. These authors also found dissolved oxygen levels should be above 8 mg/l for eggs and above 4 mg/l for juveniles.

Juveniles prefer well-shaded pools with plenty of overhead cover that are at least 1 m deep; highest densities are typically associated with instream cover such as undercut banks or logs and other woody debris in the pools or runs. Juveniles require water temperatures not exceeding 22-25°C for extended periods of time and oxygen and food (invertebrates) levels that remain high. Hassler (1987) found preferred temperatures are 10-15°C and preferred water velocities for juveniles are .09-.46 m/sec, depending on habitat. High turbidity is detrimental to emergence, feeding and growth of young coho. According to Hassler (1987) and Emmett et al. (1991), young and adult coho salmon are found over a wide range of substrates, from silt to bedrock.

APPENDIX D

The Effects of Bacterial Kidney Disease (BKD) on Coho Salmon and the Various Treatment Programs Being Undertaken by the DFG to Deal with This Chronic Disease

Bacterial kidney disease (BKD) and its chronic effects on coho salmon hatchery populations continues to cause the DFG concern, but the effects of this disease on wild populations is not well understood. As indicated in the main body of this petition, BKD is believed to occur in most coho salmon streams and in stocks from Iron Gate, Trinity River, Mad River and Warm Springs hatcheries. This disease also occurs in the Noyo River and Big Creek drainages where eggs are taken for artificial propagation.

<u>The effects of BKD on coho salmon.</u>

Fryer and Sanders (1981) found that BKD-infected coho salmon smolts from the Siletz River Hatchery in Oregon that were held in salt water died from BKD at a higher rate (17.2 percent) than did similar groups held in fresh water (4 percent). Sanders et al. (1992) studied the effects of BKD on the survival of downstream migrant juvenile salmonids in the Columbia River basin. They found over 20 percent of the smolts of chinook salmon, coho salmon and steelhead seined from the Columbia River before they entered the estuary were infected with BKD. Their samples included hatchery as well as wild stocks. They also found that mortality from BKD increased when fish were held in salt water as opposed to fresh water. These authors believe the results of these studies indicate BKD is a more efficient pathogen in salt water, perhaps because of the additional stresses imposed on the host during its adjustment to the ocean environment. The disease can be passed from fish to fish, so transplanting BKD infected coho stocks could potentially introduce this disease into wild coho populations although the effects of the disease on wild fish are not well known.

The DFG believes that BKD may represent a threat to recovery of wild and naturalized coho salmon stocks in Mendocino County because Warm Springs hatchery and Noyo River wild and naturalized stocks harbor this disease. We have similar concerns over coho stocks in the Scott Creek drainage, including its tributary Big Creek where the Monterey Bay Salmon and Trout Project operates a coho hatchery and rearing facility. Our experience has been that BKD is prevalent in most anadromous fish streams where fresh water rearing of young is > 6 months which consequently includes nearly all coho salmon streams. As the incidence of BKD observed in a stream system increases, we have seen survival rates of coho juveniles and subsequent return of adults decrease. In 1990, the DFG released coho young-of-year from Noyo River stocks into at least 5 Mendocino County streams (W. Jones, DFG, pers. comm.). Careful monitoring of the streams to determine success of the transplants indicated that no coho salmon returned to any of the 5 planted streams. Although there was no conclusive evidence that BKD was the primary factor in the failure of these 5 transplants, BKD could have been a contributor (W. Jones, DFG, pers. comm.).

Treatment programs being undertaken by the DFG to deal with BKD.

The DFG has been trying various ways to deal with problems caused by BKD in yearling coho salmon raised at Trinity River Hatchery (M. Willis, DFG, pers. comm.). The typical scenario for this disease was for losses to start occurring 4-6 months prior to release of the fish as yearlings and escalate each month. By release time, up to 45 percent of the fish were found to be infected with BKD. Starting with the spawning of adult coho salmon in the fall of 1991, the DFG initiated an aggressive 3-5 year program to reduce the level of BKD infection in yearling coho at Trinity River Hatchery. Ovarian fluid was collected from every female spawned, the eggs kept separated until eyed and the ones from BKD positive fish discarded.

This program has continued through the 1992 and 1993 spawning seasons (brood years) and will continue for at least another two years. Most of the progeny from brood years 1991 and 1992 were fed Erythromycin to specifically treat the BKD infection for an extended period of time. This protocol will not be used on progeny from brood year 1993 so that the benefits of Erythromycin can be evaluated for progeny from the 1994 brood year as compared to the untreated juveniles from the prior brood year. This treatment program has significantly reduced the level of BKD infection in yearling coho salmon at Trinity River Hatchery. Pre-release sampling of the first year class produced under this program indicated only 5 percent of the fish were infected with BKD. The second year class appears to be even lower. The Erythromycin-treated fish had a < 1 percent infection rate at the time of release and the second year class is doing as well or better (M. Willis, DFG, pers. comm.).

Starting with the 1992-1993 brood year, the DFG began a 3-5 year study to determine effectiveness of various treatments on BKD at our Warm Springs hatchery with the objective of increasing overall return of spawners to planted streams (R. Gunter, DFG, pers. comm.). Adult coho returning to this hatchery are generally ready to spawn immediately, so the option of injecting females with Erythromycin to help control the disease as is done at the privately operated Big Creek Hatchery is not an option. Instead, we spawn each female coho individually and extract ovarian fluid from each one, which is then analyzed separately in the laboratory. After being fertilized, the eggs from each female are isolated and incubated in separate single pass trays until the laboratory results return for each lot of eggs. Once the results are known, each egg lot is marked + or - for BKD infection, and then like lots are joined together and reared as separate groups.

When young fish reach 1 gm in size at about 1 month of age, 1/2 of each group (+ and -) is fed Erythromycin at a rate of 100 mg/kg of body weight for one month. The fish are then raised to yearling size and during this period they are monitored and mortalities are collected for analyses. A preliminary gross analysis of the mortalities experienced to date indicates our program of separate spawning of coho females, separation of eggs into different lots based on presence or absence of BKD, and subsequent Erythromycin therapy for rearing juveniles appears to be helpful in controlling BKD but has not eliminated it in the Warm Springs Hatchery (W. Cox, DFG, pers. comm.). The DFG is also adding a coded-wire tagging component to this study to determine which of the Erythromycin treated or untreated groups of juveniles survive better to return to the hatchery as adults.

The DFG is also attempting to find more effective ways of treating BKD at the Big Creek Hatchery in Santa Cruz County (D. Streig, pers. comm.). Since this hatchery, located in the Scott Creek drainage and operated by the Monterey Bay Salmon and Trout Project, began operating about 10 years ago, it has experienced problems with BKD including poor adult returns, presumably due to poor smolt survival. During the 1991-1992 brood year, all adult coho females were examined and the incidence of BKD infection was found to be about 95 percent.

Starting in the 1992-1993 brood year, the DFG started a BKD treatment program at the Big Creek Hatchery that takes advantage of a specific characteristic of this stream's coho population. Females arrive at the hatchery in a condition where they can be held in fresh water for one to three months before their eggs ripen enough for spawning. We took advantage of this situation by injecting ripening females with Erythromycin at a rate of 20mg/kg of body weight once each month until they were spawned. The adult females were examined just prior to spawning and the clinical evidence of BKD observed was near zero. In addition, the nearly 30,000 juveniles, which are progeny of the Erythromycin-treated females spawned last brood year, still being reared at the hatchery have exhibited no outward clinical evidence of BKD infection to date. Although there is presently no conclusive evidence available at this time to support this hypothesis, the Erythromycin treatment appears to have increased the fertility of coho females spawned at the hatchery last brood year. In the past 10 years, fertility of coho females spawned at this hatchery has averaged only about 40 percent. The Erythromycin-treated females this past brood year had a fertility rate of nearly 85 percent (W. Cox, DFG, pers. comm.).

The DFG operates a coho salmon egg-taking station on the South Fork Noyo

River, a drainage that also harbors BKD (W. Cox, DFG, pers. comm.). All adult female coho handled at this facility have been examined by the DFG for the past two years and we found the fish to have a high carrier rate for BKD. The BKD treatment program we are implementing at Warm Springs Hatchery may help us deal with this disease in Noyo River stocks because we take many of the eggs from this stream and raise them at the hatchery. We occasionally take eggs from Noyo River coho to the Mad River Hatchery and we have found that the progeny from these eggs that are raised at this hatchery have little to no problem with BKD. The reasons for this difference in BKD infection rates between the two hatcheries is not known, but the difference in water hardness between the two may be a factor (W. Cox, DFG, pers. comm.).

APPENDIX E

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